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Thermal Analysis Research Program Reference Manual

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Building Physics Division
Washington, DC 20234

March 1983

Sponsored by
National Bureau of Standards

and

**Building Energy Sciences Branch
Office of Building Energy Research and Development
U.S. Department of Energy
Washington, DC 20545**

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THERMAL ANALYSIS RESEARCH PROGRAM REFERENCE MANUAL

George N. Walton

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

The Thermal Analysis Research Program (TARP) has been developed as a research tool for the thermal analysis of buildings. It especially aims to study the interactions of many complex heat transfer phenomena. TARP uses the detailed heat balance method for the simultaneous calculation of the energy requirements of multiple rooms. Interroom conductive and convective processes are simulated in detail. This program reference manual describes the algorithms, input, output, and program structure of TARP. The program is written to be portable and modifiable. It is written in FORTRAN 77 and has run on CDC and UNIVAC computers. Future expansions of the program are anticipated, particularly for the simultaneous simulation of the equipment performance and building thermal response.

Keywords: building energy analysis; load calculations; computer modeling;
building heat transfer.

PREFACE

This report is one of a series documenting NBS research and analysis efforts in developing energy and cost data to support the Department of Energy/National Bureau of Standards Measurements Program. It was prepared by the Thermal Analysis Group, Building Physics Division, Center for Building Technology, National Engineering Laboratory, National Bureau of Standards (NBS). This work was jointly sponsored by NBS and the Department of Energy (DoE). The development of multiroom air flow modeling was supported by DoE/NBS Task Order A008 under Interagency agreement No. EA-77-A-01-6010. This report describes a computer program which was written as part of an effort to develop a comprehensive modeling technique for predicting the simultaneous transfer of air, moisture, and heat in and through multiroom buildings.

The author wishes to acknowledge the support and direction given by Dr. T. Kusuda, Thermal Analysis Group Leader.

The computer program described in this report is intended for research purposes only. It is furnished by the government and is accepted and used by any recipient with the expressed understanding that the United States Government makes no warranty, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information and data contained in this program or furnished in connection therewith, and the United States shall be under no liability whatsoever to any person by reason of any use made thereof.

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I. INTRODUCTION

I.A BACKGROUND

The effort to encourage the design, construction, and retrofit of energy conserving buildings will be strengthened by the development of comprehensive methods for evaluating the thermal effectiveness of those buildings. Since the development of research programs such as NBSLD [1], there has been a proliferation of public and private energy analysis computer programs. Computer assisted analysis is increasingly used in building design. Public domain research programs have served as sources of validated algorithms and of simulated performance for the testing of the design programs. The majority of current building thermal simulation computer programs are based upon single room methods. It was assumed that the conditions in one room were not significantly affected by conditions in another. This was a good assumption because the low cost of energy made it common practice to keep near constant temperatures in all rooms. Similarly, occupant comfort was not a significant consideration in the early programs because sufficient energy would always be available to achieve comfort. Detailed analysis of moisture migration was unnecessary because moisture could always be mechanically removed to maintain comfort or prevent condensation. The increasing cost of energy has led to the use of natural heating and cooling techniques which have gone beyond those assumptions. Significant variations in room temperatures can be expected as unoccupied rooms are left unheated and uncooled or as "sun spaces" are built on homes to help heat them by natural convection. Increased temperature ranges are allowed in work areas with occupants expected to adjust amounts of clothing to maintain comfort. Natural ventilation cooling might lead to significant moisture problems. Many other phenomena are poorly understood or inadequately modeled in existing programs. Simulation of the complex interactions among the many phenomena in real buildings is especially important.

An improved research-oriented program is needed to allow the detailed study of simultaneous air, heat, and moisture transfer in and through a building with complex internal architecture. Such a research program must be easily expandable to test the simulation of new features. This requirement implies that the program should have a simple structure and be well-documented. The program should also be able to handle simple or very complex problems efficiently, and it should be portable so that many researchers can use it.

I.B OBJECTIVES

The objective of this effort is to develop a state-of-the-art research-oriented computer program for the thermal analysis of buildings together with the documentation necessary for its use.

This computer program is called the Thermal Analysis Research Program (TARP). The name was chosen to emphasize that this is to be more than an energy/loads predictor. It aims is to study the interactions of many factors of the thermal performance of buildings. Also, features which would have enhanced the usability of the program for building designers and engineers have given way to research features. In its present version it is capable of

computing room loads and temperatures by simultaneously considering conduction and air movements between all rooms in a building. This program provides the framework for the integration of many more advanced simulation features.

I.C SCOPE

This report is the documentation of the algorithms, user-interface, and computer code of TARP in its present form. It provides a detailed description of the structure and mathematical methods of the program. It is not intended to be a tutorial for persons who are totally unfamiliar with energy analysis programs and methods.

Chapter II is an introduction to the capabilities, structure, and use of the program.

Chapter III reviews the algorithms that the program uses to compute the building energy and air flows.

Chapter IV explains how buildings are described by the input language.

Chapter V describes the various output reports available to the user.

Chapter VI gives the information necessary to understand (and hence modify) the computer code.

This report uses an outline organization to serve two purposes. It will allow easier updating of the documentation as the program evolves. It also allows a simple way to handle the many cross-references within the report. Any of the chapters may refer to details of the input or algorithms. The form of an input reference is: (3.2.5). It may consist of 1, 2, or 3 numbers separated by periods. It refers to the detailed input description in chapter IV, section C. The full reference may be considered (IV.C.3.2.5) with the "IV.C" implied. The form of an algorithm reference is: (B.2.4). It consists of a letter and optional numbers and refers to information in chapter III. The full reference may be considered (III.B.2.4).

References are indicated by brackets and are listed at the end of each section.

REFERENCES

- [1] Kusuda, T., "NBSLD, the Computer Program for Heating and Cooling Loads in Buildings," NBS Building Science Series 69, (July 1976).

II. PROGRAM OVERVIEW

II.A SIMULATION CAPABILITIES

The Thermal Analysis Research Program uses detailed heat balance techniques to compute room loads. It may be used to evaluate single "design" days or it may use up to one year of measured weather data. A large number of occupant usage features may be scheduled with hourly, daily, and seasonal variations. The effects of temperature drifts in response to various control strategies can be accurately evaluated. Input and output may be in English or metric units. Other capabilities can be grouped by the three modes of heat transfer.

Conduction: Transient conduction effects are modeled by "conduction transfer functions" which are extensions of response factors. They model the heat storage effects of walls, furnishings, and partitions between rooms. Movable insulation is closely approximated by a massless insulation model with appropriate controls which may be applied over windows or walls.

Radiation: The transmittance and absorptance of windows is computed from the optical properties of the window panes. There may be up to four panes which may be heat absorbing or have reflective films. Shading coefficients may be used for windows which cannot be described in terms of their components. The shadowing and distribution of sunlight on surfaces may be calculated in several levels of detail up to the amount of light transmitted through windows onto each surface of the room. The effects of emissivity are modeled for both interior and exterior surfaces. There is a simple model to account for the energy savings of daylighting.

Convection: The program uses variable interior and exterior convection coefficients as functions of temperature difference and system induced flow velocity when appropriate. It can compute infiltration and the natural flow of air between rooms caused by wind and thermal forces. There is an alternative simple model for infiltration with options of ventilation cooling, a whole house fan, and controlled air mixing between two rooms.

TARP is an evolutionary development of the BLAST [1,2] computer program. BLAST is a user, rather than research, oriented program with equipment simulation capabilities not included in TARP. TARP provides more detailed models for air movement and multiroom analysis. It is also more portable and easier to modify.

II.B PROGRAM STRUCTURE

The program is written almost entirely in FORTRAN 77. This is a standard language which has been or is being implemented on most large and medium size computers. The handling of character data and direct access files help to make this language machine independent. The TARP should be portable except for some conversions from single to double precision and replacing the use of BLAST weather tapes. The PARAMETER feature of FORTRAN 77 is used extensively in modifiable array dimensions so the TARP can handle different size problems.

The TARP is divided into two subprograms: the input processor (IP) and the loads calculator (LC). This structure is illustrated in figure II.1. The IP checks the user input, prepares input files for the LC, and reports the array sizes that the LC will require. The LC performs the building loads simulation and reports the results. This separation of subprograms allows a reduction in computer core requirements. The IP uses minimal array sizes because it processes the input one element (surface, schedule, material, etc.) at a time. The LC uses large arrays which consider these elements simultaneously. The IP and LC may be run as separate jobs when it is necessary to recompile the LC for correct array sizes, or they may be run as a single job if the LC is known to have sufficiently large arrays.

The input processor is divided into four major sections. These correspond to the input language sections (III.C) which they process. This sectioning allows further reductions in core requirements by the use of overlays (or segments). A small input processor is important to allow the fast job turn-around necessary to quickly debug the user input deck. Each section contains several subroutines which process the input language "keys" plus others for special elements of certain keys. The largest of these special routines are the two groups of subroutines which evaluate the conduction transfer functions and the window optics.

The loads calculator is divided into three sections. The first reads the input file created by the IP and fills the LC arrays. It checks for sufficient array space and performs some checks which require that all data for the problem description be present in the arrays. The second section uses the geometric and optical descriptions of the building surfaces to compute solar gain factors for various periods of the year. The third section does the actual heat balances necessary to compute the multi-room loads. It does this on an hour-by-hour basis.

II.C EXAMPLE RUN

The following example calculation is designed to show how a building can be simulated with TARP. The building configuration was chosen to emphasize interzone effects. It is a "passive solar" design as shown in figure 2. The building is a townhouse configuration with 8 inch thick masonry walls separating it from identical units to the east and west. The gross floor area is 1584 ft². The exterior walls and roof are wood frame construction with insulation R values of 19 and 30 respectively. The house is divided into three major zones: a north zone for bedrooms, a center zone for the main living area, and a south zone for the kitchen/utility area. Each zone has a different internal gain profile consistent with its function. At the top of the center zone is a south-facing 120 ft² double pane clerestory which is intended to allow sun to shine directly onto the 8 inch thick masonry wall which separates the north and center zones. The south exterior walls includes 80 ft² (23 percent of wall area) of double pane window where the sun is intended to shine directly on the uncarpeted slab floor. The north and center zones have carpet on the slab. The partition between the south and center zones is a nonmassive wood frame and drywall construction.

The TARP input for the example is shown in figure 3. The input begins by describing project data in the first nine lines between "PROJECT [" and "]". A project description is given; the location is described; ground temperatures are given. Then there is a description of the weather between "DDY(" and ")" on the following line. This sets up a mild, late winter condition when the solar and internal gains nearly offset the infiltration and conduction losses. The low temperature (LOW) for the day is 30F and the high (HIGH) is 50F. A clear sky (CLR) for 21 February (DATE) is assumed. A 15 mph (WS=1320 ft/min) wind blows from the northwest (DIR=315).

The next section is called the "LIBRARY". It is used to define certain features which are referred to by the name in later sections of the input. The first few entries in the library section begin with "DS" which stands for day-schedule. A day-schedule is a list of 24 values, one for each hour of the day. The third day-schedule is given the name "ON" to indicate that it is being used to describe the occupancy schedule in the north zone. This day-schedule is used in the week-schedule (WS) which has the name "OCCN". A week-schedule is a collection of day-schedules, one for each day of the week plus holidays and other special days. The command WD=ON will assign day-schedule ON to all week days. The same day-schedule will also apply for other day types by default since no other day types are specified. Building materials (MATL) are described in a similar manner. The first material is a gypsum wallboard given the name "GYP", and having a conductivity (K) of .42 Btu/h·ft·F, a density (D) of 45 lbm/ft³, and a specific heat (CP) of 0.3 Btu/lbf. The wallboard is used in the first wall construction (CONS) named "WL-I". This lists the thickness and name of each material layer in the wall listed from outside to inside. There is 0.0521 ft (.625 in) of GYP as the inside surface. The final entries in the library ("CPFL", "CDS", and "CWS") describe the control of the zone temperatures.

The "BUILDING" section gives commands controlling the heat balance simulation and descriptions of the roof overhangs.

There are three "ZONE" sections to describe the three zones of the example building. Each zone is identified by a user supplied name, e.g., "NORTH". Activities related to the entire zone are the temperature control (CTRL) and people (PEO), lights (LIT), and equipment (EQP) loads. There are three people maximum (CAP=3) in the zone. The hourly number of people is determined by that maximum and the previously defined week-schedule (WS=OCCN). The other activities have similar capacities and schedules. The rest of the zone description defines the surfaces, both envelope and internal, of the zone. The mass (MASS) of furnishings is handled by a single surface of appropriate density and area. "SRF" then describes most of the north wall of the zone as an exterior (EX), opaque (OP), base surface (BS). It is made of the previously defined WL-I construction. The wall faces north (AZM=0) and is 41 ft long by 8 ft high (SIZE). It is located relative to the other surfaces of the building by the origin (ORG) command. The next line of input specifies a window on the wall. The window is an exterior (EX), transparent (TR), subsurface (SS) made of the WDW2 construction. Its size is made to represent all windows on the north wall. Openings in the wall for identification are combined into a single area under the "AFS" command. The next surface command describes the remainder of

the north wall: the portion at the studs which is construction WL-S. Four lines later there is a description of the massive partition described as an interior (IN), opaque (OP), base surface (BS). It is thermally connected to the center zone by the command "ZONE=CENTER".

Figure 4 shows the computed loads for the sample run. The report is headed by the project, location, and environment descriptions. Then the following values are presented for each zone: Total heating and cooling requirements, peak heat and cooling loads, maximum zone air temperatures, hours at peak heating capacity (HX), other heating hours (HT), ventilating hours (V), cooling (below peak capacity) hours (CL), and hours at peak cooling capacity (CX). Building-wide values are summarized by the line labeled "TOTAL:". These values include the total heating and cooling requirements for all zones, the peak coincident heating and cooling loads, and maximum and minimum of all zone temperatures. The hour and day are reported for the occurrence of the peak loads and temperatures.

This example was not intended to provide complete instruction. The user should read the remainder of the program documentation before attempting to run TARP.

REFERENCES

- [1] Hittle, D. C., "The Building Loads Analysis and System Thermodynamics (BLAST) Program, Version 2.0: User Manual", CERL Technical Report E-153, (Construction Engineering Research Laboratory, 1979).
- [2] Herron, D., Walton, G., Lawrie, L., "Building Loads Analysis and System Thermodynamics (BLAST) Program Users Manual -- Volume One Supplement (Version 3.0), CERL Technical Report E-171, (Construction Engineering Research Laboratory, 1981).

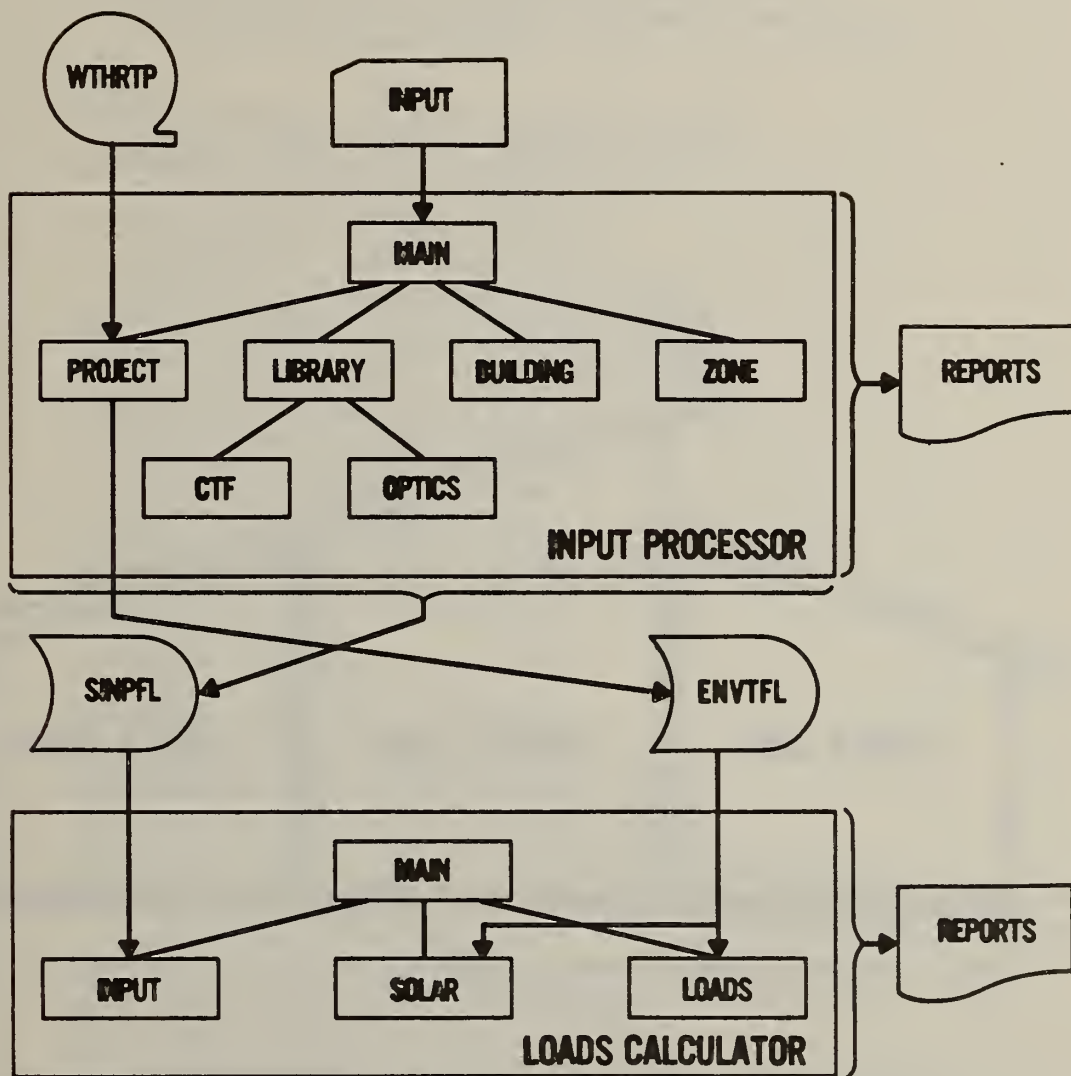


Figure II.1 Structure of the Thermal Analysis Research Program

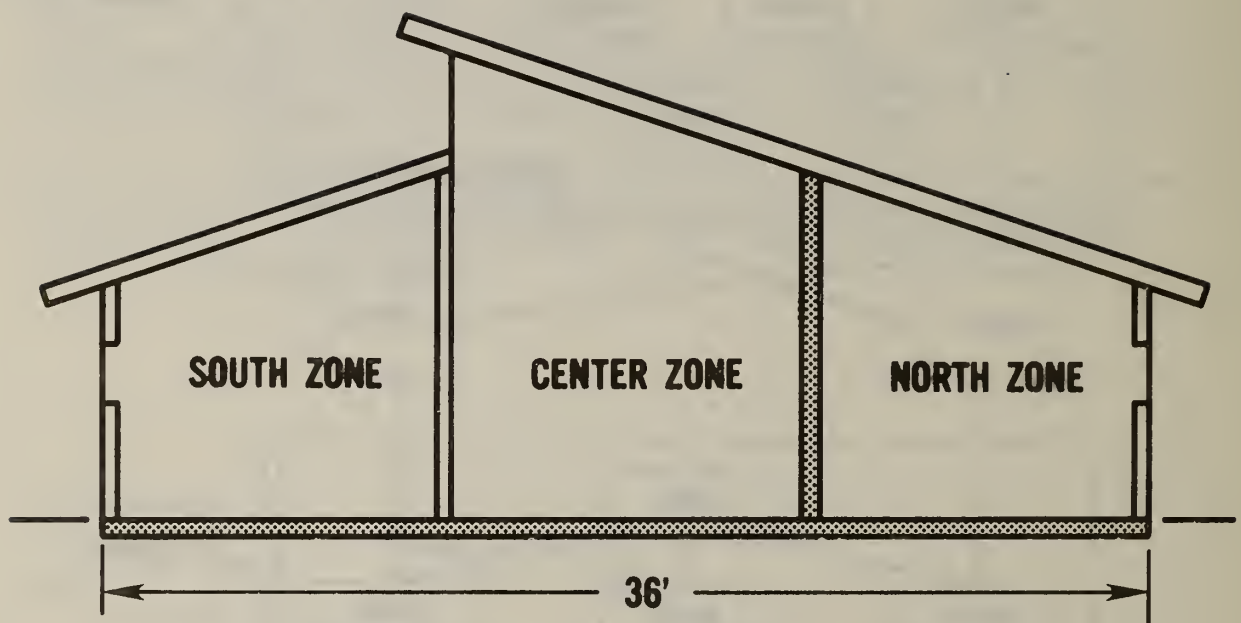


Figure II.2 House configuration for example problem

```

1 PROJECT C
2 RC(DEM/UIIN=ENGLISH/UOUT=ENGLISH/
3   DESC='THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN')
4 RPT(RNOS = 9)
5 LOC(DESC='COLUMBIA, MO.'/LATD=38.9/LONG=92.3/TZ=6)
6 GRND(GRT=40,42,48,55,62,67,70,69,63,55,48,42)
7 DDY(DESC='MILD WINTER'/HIGH=50/LOW=30/WB=40/DATE=21FEB/
8   CLR=1./MON/WS=1320/DIR=315)
9 ]
10 LIBRARY C
11 DS(NAME=NONE/DESC='ZERO ALL HOURS'/FFC=24*0)
12 DS(NAME=FULL/DESC='ONE ALL HOURS'/FFC=24*1)
13 DS(NAME=ON/DESC='NORTH OCCUPANCY'/
14   FFC=6*1,.5,.16,8*0,4*.16,2*.33,.67,1)
15 DS(NAME=OC/DESC='CENTER OCCUPANCY'/
16   FFC=16*0,3*.17,.67,.5,.67,.17,0)
17 DS(NAME=OS/DESC='SOUTH OCCUPANCY'/
18   FFC=6*0,.5,.5,8*0,2*.33,.67,2*.16,3*0)
19 WS(NAME=OCCN/DESC='NORTH OCCUPANCY'/WD=ON)
20 WS(NAME=OCCC/DESC='CENTER OCCUPANCY'/WD=OC)
21 WS(NAME=OCCS/DESC='SOUTH OCCUPANCY'/WD=OS)
22 DS(NAME=LN/DESC='NORTH LIGHTING'/
23   FFC=6*0,.7,.7,8*0,2*.33,4*.7,.4,0)
24 DS(NAME=LC/DESC='CENTER LIGHTING'/
25   FFC=16*0,.5,5*.7,.3,0)
26 DS(NAME=LS/DESC='SOUTH LIGHTING'/
27   FFC=6*0,.7,.7,8*0,5*.7,3*0)
28 WS(NAME=LITN/DESC='NORTH LIGHTING'/WD=LN)
29 WS(NAME=LITC/DESC='CENTER LIGHTING'/WD=LC)
30 WS(NAME=LITS/DESC='SOUTH LIGHTING'/WD=LS)
31 DS(NAME=EN/DESC='NORTH EQUIPMENT'/
32   FFC=20*0,3*1,0)
33 DS(NAME=EC/DESC='CENTER EQUIPMENT'/
34   FFC=16*0,4*1,4*0)
35 DS(NAME=ES/DESC='SOUTH EQUIPMENT'/
36   FFC=6*.3,2*1,8*.3,2*1,3*.7,3*.3)
37 WS(NAME=EQPN/DESC='NORTH EQUIPMENT'/WD=EN)
38 WS(NAME=EQPC/DESC='CENTER EQUIPMENT'/WD=EC)
39 WS(NAME=EQPS/DESC='SOUTH EQUIPMENT'/WD=ES)
40 WS(NAME=CONST/DESC='CONSTANT 100%'/ALL=FULL)
41 MATL(NAME=GYP/DESC='GYPSUM WALLBOARD'/K=.42/D=45./CP=.3)
42 MATL(NAME=WD-S/DESC='SOFTWOOD'/K=.0675/D=32./CP=.33)
43 MATL(NAME=SHTH/DESC='INTERMEDIATE DENSITY BUILDING BOARD SHEATHING'/
44   K=.034/D=22./CP=.31)
45 MATL(NAME=C-HW/DESC='HEAVY CONCRETE'/K=1.0/CP=.2/D=140.)
46 MATL(NAME=B1/DESC='AIRSPACE RESISTANCE'/R=.91/AIR)
47 MATL(NAME=R5/DESC='R5 POLYSTYRENE'/R=5.)
48 MATL(NAME=R19/DESC='R19 INSULATION'/R=19.)
49 MATL(NAME=R30/DESC='R30 INSULATION'/R=30.)
50 MATL(NAME=SPDS/DESC='STANDARD GLASS'/GLASS/R=.0236/TRNS=.86)
51 MATL(NAME=ASH/DESC='ASPHALT SHINGLES'/K=18.16/D=70/CP=.3)
52 MATL(NAME=DIRT/K=.1/D=65./A=.70)

```

Figure II.3 TARP input for example problem

```

53  MATL(NAME=AL/DESC='ALUMINUM SIDING'/K=128/D=171./CP=.2)
54  MATL(NAME=CPT/DESC='CARPET & PAD'/R=2.08)
55  CONS(NAME=WL-I/DESC='EXTERIOR WALL - INSULATION AREA'/
56      MATL=.0052,AL,.0417,SHTH,0,R19,.0521,GYP)
57  CONS(NAME=WL-S/DESC='EXTERIOR WALL- STUD AREA'/
58      MATL=.0052,AL,.0417,SHTH,0,R19,.0521,GYP)
59  CONS(NAME=PTN-A/DESC='PARTITION - AIR SPACE AREA'/
60      MATL=.0521,GYP,0,B1,.0521,GYP)
61  CONS(NAME=PTN-S/DESC='PARTITION - STUD AREA'/
62      MATL=.0521,GYP,.292,WD-S,.0521,GYP)
63  CONS(NAME=WDW2/DESC='2 PANE WINDOW'/
64      MATL=0,SPDS,0,B1,0,SPDS)
65  CONS(NAME=FRAME/DESC='WINDOW FRAME'/MATL=0.1354,WD-S)
66  CONS(NAME=RF-T/DESC='CEILING/ROOF - TRUSS AREA'/
67      MATL=.0104,ASH,.0417,WD-S,.625,WD-S,.0417,GYP)
68  CONS(NAME=RF-I/DESC='CEILING/ROOF - INSULATION AREA'/
69      MATL=.0104,ASH,.0417,WD-S,0,R30,.0417,GYP)
70  CONS(NAME=PTN-M/DESC='MASSIVE PARTITION'/MATL=.667,C-HW)
71  CONS(NAME=SLAB-C/DESC='SLAB WITH CARPET'/
72      MATL=.5,DIRT,0,R5,.333,C-HW,0,CPT)
73  CONS(NAME=SLAB-T/DESC='SLAB WITH TILE'/
74      MATL=.5,DIRT,0,R5,.333,C-HW)
75  CPFL(NAME=P1/DESC='HEATING SETBACK'/CAP=1,0/TMP=60,62)
76  CPFL(NAME=P2/DESC='STANDARD HEATING'/CAP=1,0/TMP=68,70)
77  CDS(NAME=HN/DESC='NORTH HEATING'/CPFL=6*P1,2*P2,8*P1,6*P2,2*P1)
78  CDS(NAME=HC/DESC='CENTER HEATING'/CPFL=16*P1,6*P2,2*P1)
79  CDS(NAME=HS/DESC='SOUTH HEATING'/CPFL=6*P1,2*P2,8*P1,5*P2,3*P1)
80  CWS(NAME=HEATN/DESC='NORTH HEATING'/WD=HN)
81  CWS(NAME=HEATC/DESC='CENTER HEATING'/WD=HC)
82  CWS(NAME=HEATS/DESC='SOUTH HEATING'/WD=HS)
83  ]
84  BUILDING [
85      SIM(SLDS=3/HTB=0/FLOW/CNVG=.1,.01,.34,12)
86      DSS(AZM=180./TILT=153.4/ORG=0,12,16/SIZE=44,2)
87      DSS(AZM=180./TILT=206.6/ORG=0,0,8/SIZE=44,2)
88      DSS(AZM=0./TILT=116.6/ORG=0,36,8/SIZE=44,2)
89  ]
90  ZONE [
91      GEOM(NAME=NORTH)
92      CTRL(CWS=HEATN/HEAT=12)
93      PEO(WS=OCCN/CAP=3)
94      LIT(WS=LITN/CAP=1.4)
95      EQP(WS=EQPN/CAP=1.0)
96      MASS(CONS=PTN-A/AREA=480)
97      SRF(EX/OP/BS/CONS=WL-I/AZM=0/ORG=44,36,0/SIZE=41,8)
98          SRF(EX/TR/SS/CONS=WDW2/ORG=12,5,-.25/SIZE=20,2)
99          AFS(AREA=0.2/EXP=.65)
100     SRF(EX/OP/BS/CONS=WL-S/AZM=0/ORG=3,36,0/SIZE=3,8)
101     SRF(EX/OP/BS/CONS=RF-T/AZM=0/ORG=44,36,8/SIZE=41,8.95/TILT=26.6)
102         AFS(AREA=0.1/EXP=.65)
103     SRF(EX/OP/BS/CONS=RF-I/AZM=0/ORG=3,36,8/SIZE=3,8.95/TILT=26.6)
104     SRF(IN/OP/BS/CONS=PTN-M/AZM=180/ORG=0,24,0/SIZE=44,12/ZONE=CENTER)

```

Figure II.3 (continued)


```

105     AFS(AREA=0.5/EXP=.50)
106     SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,36,0/VRTS=12,0, 12,12, 0,8)
107     SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,24,0/VRTS=12,0, 12,8, 0,12)
108     SRF(EX/OP/BS/CONS=SLAB-C/AZM=180/ORG=0,36,0/SIZE=44,12/TILT=180)
109     OSC(TGP=1)
110 ]
111 ZONE C
112     GEOM(NAME=CENTER)
113     CTRL(CWS=HEATC/HEAT=12)
114     PED(WS=OCCC/CAP=3)
115     LIT(WS=LITC/CAP=1.4)
116     EQP(WS=EQPC/CAP=1.0)
117     MASS(CONS=PTN-A/AREA=480)
118     SRF(EX/OP/BS/CONS=FRAME/AZM=180/ORG=0,12,12/SIZE=44,3)
119     SRF(EX/TR/SS/CONS=WDW2/ORG=2,0,-.25/SIZE=40,3)
120     AFS(AREA=0.25/EXP=.65)
121     SRF(EX/OP/BS/CONS=RF-T/AZM=0/ORG=44,24,12/SIZE=41,8.95/TILT=26.6)
122     AFS(AREA=0.1/EXP=.65)
123     SRF(EX/OP/BS/CONS=RF-I/AZM=0/ORG=3,24,12/SIZE=3,8.95/TILT=26.6)
124     SRF(IN/OP/BS/CONS=PTN-A/AZM=180/ORG=3,12,0/SIZE=41,12/ZONE=SOUTH)
125     AFS(AREA=0.5/EXP=.50)
126     SRF(IN/OP/BS/CONS=PTN-S/AZM=180/ORG=0,12,0/SIZE=3,12/ZONE=SOUTH)
127     SRF(IN/OP/BS/CONS=PTN-M/AZM=0/ORG=44,24,0/SIZE=44,12/ZONE=NORTH)
128     AFS(AREA=0.5/EXP=.50)
129     SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,24,0/VRTS=12,0, 12,16, 0,12)
130     SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,12,0/VRTS=12,0, 12,12, 0,16)
131     SRF(EX/OP/BS/CONS=SLAB-C/AZM=180/ORG=0,24,0/SIZE=44,12/TILT=180)
132     OSC(TGP=1)
133 ]
134 ZONE C
135     GEOM(NAME=SOUTH)
136     CTRL(CWS=HEATS/HEAT=12)
137     PED(WS=OCCS/CAP=3)
138     LIT(WS=LITS/CAP=1.4)
139     EQP(WS=EQPS/CAP=9.4/LOST=.4)
140     MASS(CONS=PTN-A/AREA=480)
141     SRF(EX/OP/BS/CONS=WL-I/AZM=180/ORG=0,0,0/SIZE=41,8)
142     SRF(EX/TR/SS/CONS=WDW2/ORG=12,3,-.25/SIZE=20,4)
143     AFS(AREA=0.2/EXP=.65)
144     SRF(EX/OP/BS/CONS=WL-S/AZM=180/ORG=41,0,0/SIZE=3,8)
145     SRF(EX/OP/BS/CONS=RF-T/AZM=180/ORG=0,0,8/SIZE=41,8.95/TILT=26.6)
146     AFS(AREA=0.1/EXP=.65)
147     SRF(EX/OP/BS/CONS=RF-I/AZM=180/ORG=41,0,8/SIZE=3,8.95/TILT=26.6)
148     SRF(IN/OP/BS/CONS=PTN-A/AZM=0/ORG=44,12,0/SIZE=41,12/ZONE=CENTER)
149     AFS(AREA=0.5/EXP=.50)
150     SRF(IN/OP/BS/CONS=PTN-S/AZM=0/ORG=3,12,0/SIZE=3,12/ZONE=CENTER)
151     SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,12,0/VRTS=12,0, 12,8, 0,12)
152     SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,0,0/VRTS=12,0, 12,12, 0,8)
153     SRF(EX/OP/BS/CONS=SLAB-T/AZM=180/ORG=0,12,0/SIZE=44,12/TILT=180)
154     OSC(TGP=1)
155 ]

```

Figure II.3 (concluded)

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BUILDING LOADS FOR

THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN

COLUMBIA, MO.

MILD WINTER

ZONE	TOTAL HEATING (KBTU)	TOTAL COOLING (KBTU)	PEAK HEATING (KBTUH)	PEAK COOLING (KBTUH)	MAX TEMP (F)	MIN TEMP (F)	HX	HT	V	CL	CX
NORTH	51.02	0.00	10.166	0.000	69.28	61.90	0	10	0	0	0
CENTER	1.13	0.00	1.126	0.000	73.10	64.10	0	2	0	0	0
SOUTH	.31	0.00	.308	0.000	77.86	67.96	0	1	0	0	0
TOTAL:	5.245E+01	0.	10.473	0.000	77.86	61.90					

MAX HEATING OCCURS AT HOUR 7 ON 21FEB
MAX TEMP OCCURS AT HOUR 18 ON 21FEB
MIN TEMP OCCURS AT HOUR 6 ON 21FEB

Figure II.4 Calculated loads for example problem

III. ALGORITHMS

III.A INTRODUCTION

III.A.1 THE HEAT BALANCE METHOD

TARP is a large collection of algorithms which perform a simultaneous evaluation of multi-room temperatures and energy requirements as affected by dynamic external and internal thermal conditions. The overall simulation process is best explained in terms of a single room. The calculation of the room air temperature is based on a heat balance on the room air. The convective gains from the room surfaces and internal sources plus the sensible gain from incoming air plus the energy added by the air handling system must equal zero.

$$CE + \sum HC_i * S_i * (T_i - TZ) + \sum F_j * C_p * (TS_j - TZ) + L = 0 \quad (A.1.1)$$

where

CE = energy convected from internal sources
S_i = area of surface i
HC_i = convection coefficient of surface i
T_i = temperature of surface i
TZ = room air temperature
F_j = mass flow of air through opening j
C_p = specific heat of air
TS_j = temperature of the air through opening j
L = energy from the air handling system

The summations apply to all surfaces/openings which are part of the room. The values of the surface temperatures, T_i, are obtained by evaluating a heat balance at every surface of the room using an assumed room temperature. A better estimate of the room temperature is then obtained by solving equation A.1.1 for TZ. Repeating this process leads to successively better approximations of the surface and air temperatures. The process is rapidly convergent. Multiple rooms can be handled within the iterative scheme given an appropriate data structure and proper heat balances on the surfaces between rooms. Multiple rooms are thermally connected by conductive, convective, and radiative heat transfer. The following sections describe the algorithms for the various heat transfer mechanisms and thermal driving functions which culminate in multi-room heat balances.

III.A.2 TABLE OF SYMBOLS

The following symbols are used frequently in the algorithm descriptions. Symbols which are local to an algorithm are defined as they occur.

Subscripts:

Subscripts may be omitted if context is clear.

Symbol	Meaning
a	ambient air
g	ground surface
i	surface i
j	surface j (usually meaning opposite side of surface i)
k	order of conduction transfer functions (CTF)
m	number of CTF
m	zone m (usually meaning adjacent to zone n)
n	zone n
t	time
s	sky
sg	surface to ground
ss	surface to sky

Summation limits:

NC	number of temperature CTF
NF	number of flux CTF ($NF \leq NC$)
NS	number of surfaces
NZ	number of zones

Parameters:

Symbol	Units	Meaning
α_i		absorptance of surface i for short wave radiation
ϵ_i		emittance of surface i for long wave radiation
g	m/s ²	gravitational constant (9.80)
ρ_i		reflectance of surface i
σ	W/m ² K ⁴	Stefan-Boltzman constant (5.6688E-8)
τ_i		transmittance of surface i
θ_i		angle of incidence of sun's rays on surface i
ϕ_i		surface tilt angle
ψ_i		surface azimuth angle
A_i	m ²	area of opening i
C_p	Wh/kgK	specific heat (often refers to air - 1004.)
CE_n	W	convective gain from all internal sources in zone n
CI_i	W/m ²	convective flux from zone air to (inside of) surface i
CO_i	W/m ²	convective flux from environment to surface i
D	kg/m ³	density
F	kg/s	mass flow rate
F_{ij}		radiation interchange factor from surface i to surface j
HA_i	W/m ² K	surface i outside convection film coefficient
HC_i	W/m ² K	surface i inside convection film coefficient
HG_i	W/m ² K	surface i radiative conductance (outside surface to ground radiant temperature)
HO_i	W/m ² K	overall outside surface conductance
HR_i	W/m ² K	surface i radiative conductance (inside surface to zone mean radiant temperature)
HS_i	W/m ² K	surface i radiative conductance (outside surface to sky radiant temperature)

I_b	W/m^2	intensity of solar beam (direct) radiation
I_d	W/m^2	intensity of solar diffuse radiation
I_s	W/m^2	intensity of sky diffuse radiation (sky brightness)
I_g	W/m^2	intensity of ground reflected radiation
$J_{i,k}$		flux referring CTF
$KI_{i,t}$	W/m^2	inward conductive flux at inside of surface i at time t
$KIP_{i,t}$	W/m^2	portion of inward conductive flux based on previous temperature and flux history terms
$KO_{i,t}$	W/m^2	outward conductive flux at outside of surface i at time t
$KOP_{i,t}$	W/m^2	portion of outward conductive flux based on previous temperature and flux history terms
M	W/K	capacitance rate (mass flow times specific heat)
P	N/m ²	pressure
PB	N/m ²	barometric pressure
PS_i	N/m ²	pressure difference across surface i due to stack effect
PW_i	N/m ²	pressure difference across surface i due to wind
QI_i	W/m^2	total radiant flux absorbed at inside of surface i
QL_n	W	total long wave radiation created in zone n
QLI_i	W/m^2	long wave radiant flux absorbed at inside of surface i
QO_i	W/m^2	total radiant flux absorbed at outside of surface i
QS_n	W	total diffuse short wave radiation entering and created in zone n
QSI_i	W/m^2	short wave radiant flux absorbed at inside of surface i
QSO_i	W/m^2	short wave radiant flux absorbed at outside of surface i
S_i	m ²	area of surface i
T	C	temperature
T	K	absolute temperature (= T + 273.15K)
\bar{T}_a	C	temperature of outside (ambient) air
T_g	C	ground surface (radiant) temperature
$TI_{i,t}$	C	temperature of inside of surface i at time t
TM	C	temperature of movable insulation (zone side or outside depending on placement)
$TO_{i,t}$	C	temperature of outside of surface i at time t
TR_n	C	mean radiant temperature of zone n
T_s	C	sky radiant temperature
TZ_n	C	temperature of zone air
U	W/m^2K	conductance (U-value) of a construct
UM_i	W/m^2K	conductance of movable insulation on surface i
V_a	m/s	wind speed (measured value)
V_{az}	m/s	wind speed at height z
$V_{az\psi}$	m/s	wind speed relative to surface at height z and orientation ψ
X	m	X-coordinate of a point
X_i		flow exponent
$X_{i,m}$	W/m^2K	outside (eXterior) CTF
Y	m	Y-coordinate of a point
$Y_{i,m}$	W/m^2K	cross CTF
Z	m	Z-coordinate of a point
Z	m	height (of surface i or zone n)
$Z_{i,m}$	W/m^2K	inside (Zone) CTF

III.B ENVIRONMENT

III.B.1 TIME

III.B.1.1 TIME OF DAY

Currently, TARP uses a one hour time step. The time from midnight to 1:00 AM is hour number 1; from 1:00 to 2:00 AM is hour 2; ...; and from 11:00 PM to midnight is hour 24. The hour number (t_g) is used as an index in the program to select array elements. Most driving functions, such as solar radiation, wind, and scheduled activities, use their average values for the hour. Temperatures are for the mid-point of the hour. The one hour time step was chosen because it is the shortest for which weather data is commonly available, and it is possibly the longest for significant detail in the thermal analysis. The time step can be changed by slight modification of the program, primarily in the handling of day (24 hour) schedules.

During some portions of the year, daylight savings time (DST) is in effect. DST hour numbers (t_d) are given by: $t_d = t_g + 1$. TARP responds to DST by operating scheduled activities according to t_d hour numbers and the environmentally controlled activities and parameters according to t_g hours.

III.B.1.2 DATES

The TARP includes a package of routines to compute dates in various forms for different calculational needs. All use integer arithmetic (remainders of divisions are truncated). The starting values are the year (YR), month (MO) and day-of-month (DM). For example the date December 31, 1980 has YR = 1980 (all 4 digits required), MO = 12, and DM = 31. The leap year indicator (LY) is determined by the YR. LY = 1 if YR is a leap year, 0 if it is not. A year is not a leap year if it is not evenly divisible by 4, or if it is evenly divisible by 100 but not 400. Otherwise, it is a leap year. Note that LY(1900) = 0 and LY(2000) = 1. The number of days in each month (LM) is given by

LM(MO=1) = 31
LM(2) = 28 + LY
LM(3) = 31
LM(4) = 30
etc.

The day-of-year number (DY) is a continuous count of days beginning at 1 January. It can be computed by

$$DY = DM + \sum_{m=0}^{MO-1} LM(m) \quad (B.1.1)$$

For MO=1, the sum is zero.

The Julian date (JD) is the most powerful date representation. It is a continuous count of days from 1 January 4713 B.C. Any number of days added to or subtracted from a JD is a valid JD. The following algorithms [1] convert between conventional and Julian dates:

$$\begin{aligned} L &= (MO - 14) / 12 \\ JD &= DM - 32075 + 1461 * (YEAR + 4800 + L) / 4 \\ &\quad + 367 * (MO - 2 - 12 * L) / 12 \\ &\quad - 3 * ((YEAR + 4900 + L) / 100) / 4 \end{aligned} \quad (B.1.2)$$

$$\begin{aligned} J &= JD + 68569 \\ N &= 4 * J / 146097 \\ K &= J - (146097 * N + 3) / 4 \\ YEAR' &= 4000 * (K + 1) / 1461001 \\ L &= K - 1461 * YEAR' / 4 + 31 \\ MO' &= 80 * L / 2447 \\ DM &= L - 2447 * MO' / 80 \\ M &= MO' / 11 \\ MO &= MO' + 2 - 12 * M \\ YEAR &= 100 * (N - 49) + YEAR' + M \end{aligned} \quad (B.1.3)$$

The cyclic date (CD) is used in TARP to represent time periods which begin and end certain functions. They are given by

$$CD = 32 * MO + DM \quad (B.1.4)$$

The inverse relationships are equally simple.

$$\begin{aligned} MO &= CD / 32 & (B.1.5a) \\ DM &= MOD(CD, 32) & (B.1.5b) \end{aligned}$$

where

$$\begin{aligned} MOD(A, B) &= \text{the remainder of } A/B \\ &= A - (A/B) * B \quad (\text{MOD is a FORTRAN intrinsic function}) \end{aligned}$$

It is easy to use cyclic dates to determine if CD lies within a period from CD1 through CD2, inclusive.

$$\begin{aligned} \text{If}(CD2 > CD1), \text{ then } (CD > CD1 \text{ and } CD < CD2) \text{ for } CD \text{ to be in the period.} \\ \text{If}(CD1 > CD2), \text{ then } (CD > CD1 \text{ or } CD < CD2) \text{ for } CD \text{ to be in the period.} \end{aligned} \quad (B.1.6)$$

A number such as 94 can be a valid cyclic date even though it represents an impossible conventional date - 30 February. This date can be used to end activities on the last day of February without considering leap year. The logic of B.1.6 still works because 1 March has cyclic date 97.

Day-of-week numbers (DW) are assigned according to: Sunday = 1, Monday = 2, ..., Saturday = 7. DW is given from JD by:

$$DW = MOD(JD+1, 7) + 1 \quad (B.1.7)$$

Building activities typically differ on holidays from normal schedules. The standard U. S. federal holidays are:

1 January (New Year's day)
3rd Monday in February (Washington's birthday)
last Monday in May (Memorial day)
4 July (Independence day)
1st Monday in September (Labor day)
2nd Monday in October (Columbus day)
11 November (Veteran's day)
4th Thursday in November (Thanksgiving day)
25 December (Christmas)

If any of the four holidays with dates fall on a weekend, the nearest Friday or Monday becomes a holiday. Five tests can describe the federal holidays (given that MO is correct).

Mth (DW=N) in the month:

If($DW = N$ and $(DM+6)/7 = M$), DM is the holiday. (B.1.8a)

Last (DW=N) in the month:

If($DW = N$ and $DM > (LM-7)$), DM is the holiday. (B.1.8b)

Dated holiday (DM=J) on weekday:

If($DM = J$ and $DW \neq 1$ and $DW \neq 7$), DM is the holiday. (B.1.8c)

Dated holiday on Saturday:

If($DM = J-1$ and $DW = 6$), DM is the holiday. (B.1.8d)

Dated holiday on Sunday:

If($DM = J+1$ and $DW = 2$), DM is the holiday. (B.1.8e)

A test is also needed for the New Year's holiday on Friday, 31 December.

Daylight savings time is in effect from the last Sunday in April through the Saturday before the last Sunday in October.

III.B.2 PSYCHROMETRICS

The following algorithms are used to calculate the properties of moist air. They are presented as a package, but not all are required by TARP. The psychrometric package gives four ways to compute the humidity ratio depending on available information. Other values can then be computed from the humidity ratio, dry-bulb temperature, and barometric pressure. The following nomenclature is used in the psychrometric package.

T_a = Dry-bulb temperature (C)
 T_w = Wet-bulb temperature (C)
 T_d = Dewpoint temperature (C)
 TS = Saturation temperature of water at a given pressure
 PB = Barometric pressure (Pa)
 PS = Saturation pressure of water at a given temperature
 Pw = Partial pressure of water (Pa)
 W = Humidity ratio (kg/kg)
 H = Enthalpy (kJ/kg)
 RH = Relative humidity
 V = Specific volume (m³/kg)

TS and PS are computed from polynomial expressions obtained by fits to the detailed correlation [2]. These expressions are of the form

$$Y(X) = A_0 + A_1 * X + A_2 * X^2 + \dots + A_N * X^N \quad (B.2.1)$$

The coefficients for computing PS(T) (+0.02 %) are:

Range of T	A ₀	A ₁	A ₂	A ₃	A ₄
-70. to -60.	187.72756	9.7388459	.19227592	.0017092958	5.7638449E-6
-60. to -50.	304.327455	17.544515	.38850839	.0039049250	1.4989099E-5
-50. to -35.	456.91552	30.071980	.77543816	.0092327737	4.2579887E-5
-35. to -20.	578.24965	43.849126	1.3678040	.020662996	.00012607288
-20. to 0.	611.12442	50.242069	1.8540594	.037851608	.00036358829
0. to 20.	617.57030	44.857183	1.4599520	.024895806	.00041888641
20. to 40.	674.80450	34.735044	2.1525746	.0029183585	.00069389647
40. to 70.	1882.1549	-75.905764	6.0054813	-.057650288	.0010572251
70. to 100.	10003.937	-537.34244	15.931817	-.15349268	.0014076596

The coefficients for computing TS(P) (+0.005 C) are:

Range of P	A ₀	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆
0.2617 to 1.08	-80.481222	60.488509	-104.02603	116.27016			
1.08 to 3.94	-71.907528	17.059641	-7.6219223	2.2337690			
3.94 to 22.35	-62.643477	4.8931575	-.58140203	.047441082			
22.35 to 103.26	-50.166219	1.0796773	-.025433803	.00041771901			
103.26 to 617.56	-36.261166	.23970771	-.0010835426	3.3697165E-6			
617.56 to 2364.9	-21.4716785	.052658152	-3.8998869E-5	1.9227789E-8			
2364.9 to 7471.5	-6.2548222	.017442339	-3.7406571E-6	5.4267058E-10			
7471.5 to 31605.7	9.3624054	.0065309333	-4.6769042E-7	2.4048849E-11			
31605.7 to 102862.	33.328934	.0017898571	-2.7520024E-8	2.8970085E-13			
			-1.6828604E-18	4.0679479E-24			

The polynomials are faster than the ASHRAE detailed algorithm which involves a logarithm and an exponential. The other relationships are based on the ideal gas law and are generally accurate to better than 0.7 percent. The humidity ratio may be obtained from one of the following algorithms [3].

W (T_d , PB)

$$P_w = PS(T_d)$$

$$W = 0.62198 * P_w / (PB - P_w) \quad (B.2.2)$$

W (T_a , T_w , PB)

$$P' = PS(T_w)$$

$$W' = 0.62198 * P' / (PB - P')$$

$$W = [(2501. - 2.381 * T_w) * W' - (T_a - T_w)] / (2501. + 1.805 * T_a - 4.18 * T_w) \quad (B.2.3)$$

W (T_a , RH, PB)

$$P_w = RH * PS(T_a)$$

$$W = 0.62198 * P_w / (PB - P_w) \quad (B.2.4)$$

W (T_a , H)

$$W = (H - T_a) / (2501. + 1.805 * T_a) \quad (B.2.5)$$

The following values may be computed when the humidity ratio is known.

T_d (W, PB)

$$P_w = PB * W / (0.62198 + W)$$

$$T_d = TS(P_w) \quad (B.2.6)$$

RH (T_a , T_d)

$$RH = PS(T_d) / PS(T_a) \quad (B.2.7)$$

V (T_a , W, PB)

$$V = 287.055 * (1. + 1.6078 * W) * T_a / PB \quad (B.2.8)$$

H (T_a , W)

$$H = T_a + W * (2501. + 1.805 * T_a) \quad (B.2.9)$$

T_w (T_a , W, PB)

T_w is computed by iterating (B.2.3).

III.B.3 TEMPERATURES

III.B.3.1 AIR TEMPERATURES

All temperatures occur on the half-hour. Dry bulb temperature and barometric pressure are read from the weather tape. The wet bulb temperature, dew point, or relative humidity are also read to allow computation of the humidity ratio and the wet bulb temperature. For design days a temperature profile is generated between the maximum (T_a^+) and minimum (T_a^-) temperatures for the day according to

$$T_{at} = T_a^+ - f_t * (T_a^+ - T_a^-) \quad (B.3.1)$$

where f_t is given by

t:	1	2	3	4	5	6	7	8	9	10	11	12
f:	.85	.90	.94	.98	1.0	.99	.95	.89	.78	.64	.48	.31
t:	13	14	15	16	17	18	19	20	21	22	23	24
f:	.17	.06	.00	.01	.07	.16	.23	.41	.53	.63	.72	.79

These values were obtained by interpolating between the hourly temperatures given by ASHRAE [4]. This profile is for summer days. For design days the user also gives PB and T_w corresponding to T_a^+ . A humidity ratio is computed from these and used with T_a and PB to compute T_w for every hour.

III.B.3.2 SKY TEMPERATURE

The net thermal radiative flux between a horizontal surface and the sky (Q_{ss}) is given by

$$Q_{ss} = \epsilon_i * (\sigma * T_{o_i}^4 - \epsilon_s * \sigma * T_a^4) \quad (B.3.2)$$

with ϵ_s , the sky emissivity, given by the correlation [5]

$$\epsilon_s = [0.787 + .764 * \ln(T_d/273)] * (1 + .0224 * N - .0035 * N^2 + .00028 * N^3) \quad (B.3.3)$$

where

N = tenths cloud cover

TARP uses a slightly different formula for computing Q_{ss} .

$$Q_{ss} = \epsilon_i * \sigma * (T_{o_i}^4 - T_s^4) \quad (B.3.4)$$

so that

$$T_s = \sqrt[4]{\epsilon_s} * T_a \quad (B.3.5)$$

III.B.3.3 GROUND TEMPERATURES

The user specifies monthly ground temperatures. Useful advice for the selection of ground temperatures is a subject of ongoing research.

III.B.4 WIND

Wind speed increases with height according to the formula

$$V = V_0 * \beta * (Z / Z_0)^\alpha \quad (B.4.1)$$

where

V_0 = wind speed at standard conditions
 Z = height being considered
 Z_0 = standard height of wind measurements (10m)
 α, β terrain dependent coefficients given below.

Terrain Parameters for Standard Terrain Classes [6]

Class	Description	α	β
1	ocean or other body of water with at least 5km of unrestricted expanse	0.10	1.30
2	flat terrain with some isolated obstacles (buildings or trees well separated from each other)	0.15	1.00
3	rural areas with low buildings, trees, etc.	0.20	0.85
4	urban, industrial, or forest area	0.25	0.67
5	center of large city (Manhattan)	0.35	0.47

Wind speeds are usually measured at class 2 sites (airports). Therefore, the reported velocity is V_0 . Eq (B.4.1) can be rearranged to compute V_0 for V measured at non-standard sites.

III.B.5 SOLAR RADIATION

The general factors in determining solar position and solar radiation intensity are described by ASHRAE [7]. Most of that information is not repeated in the following discussion.

III.B.5.1 SOLAR POSITION

The solar position is described in terms of three direction cosines which are convenient for determining the angle of incidence of the sun's rays on a building surface (E.2.2). The following procedure is used to determine the direction cosines. The values of the solar declination angle, δ , the equation of time, ϵ , and the distance from the earth to the sun, R (in AU: 1 AU = 149,504,000 km) are determined by a U.S. Naval Observatory algorithm [8].

For a given JD, compute the number of centuries since 1900.

$$T = (JD - 2415020.5) / 36525. \quad (B.5.1)$$

Then compute the following fundamental angles (in degrees).

Mean anomaly of the sun:

$$G = 385.475833 + 35999.049750T - 0.000150T^2 \quad (B.5.2a)$$

Mean longitude of the sun:

$$L = 279.696678 + 36000.768920T + 0.000303T^2 \quad (B.5.2b)$$

Mean longitude of the moon:

$$C = 270.434164 + 481267.883144T - 0.001133T^2 \quad (B.5.2c)$$

Longitude of the ascending node of the moon's orbit:

$$N = 259.183275 - 1934.142008T + 0.002078T^2 \quad (B.5.2d)$$

Mean anomaly of Venus:

$$V = 212.603219 + 58517.803875T + 0.0001286T^2 \quad (B.5.2e)$$

Mean anomaly of Mars:

$$M = 319.529425 + 19139.858500T + 0.000181T^2 \quad (B.5.2f)$$

Mean anomaly of Jupiter:

$$J = 225.444651 + 3034.906654T \quad (B.5.2g)$$

Then compute the following values.

$$\begin{aligned} \theta = & 0.397930 \sin(L) + 0.009999 \sin(G-L) + 0.003334 \sin(G+L) \\ & - 0.000208 T \sin(L) + 0.000042 \sin(2G+L) - 0.000040 \cos(L) \\ & - 0.000039 \sin(N-L) - 0.000030 T \sin(G-L) - 0.000014 \sin(2G-L) \\ & - 0.000010 \cos(G-L-J) - 0.000010 T \sin(G+L) \end{aligned} \quad (B.5.3a)$$

$$\begin{aligned} \rho = & 1.000421 - 0.033503 \cos(G) - 0.000140 \cos(2G) \\ & + 0.000084 T \cos(G) - 0.000033 \sin(G-J) + 0.000027 \sin(2G-2V) \end{aligned} \quad (B.5.3b)$$

$$\begin{aligned} \phi = & -0.041295 \sin(2L) + 0.032116 \sin(G) - 0.001038 \sin(G-2L) \\ & - 0.000346 \sin(G+2L) - 0.000095 - 0.000080 T \sin(G) \\ & - 0.000079 \sin(N) + 0.000068 \sin(2G) + 0.000046 T \sin(2L) \\ & + 0.000030 \sin(C-L) - 0.000025 \cos(G-J) + 0.000024 \sin(4G-8M+3J) \\ & - 0.000019 \sin(G-V) - 0.000017 \cos(2G-2V) \end{aligned} \quad (B.5.3c)$$

The maximum error in θ or ϕ is .0001 AU and the maximum error in ρ is .0001 AU² for the years 1800 through 2100. This is more accurate than is needed for building thermal analysis. Equations (B.5.3a-c) can be truncated with some loss in accuracy. That loss can be estimated by the sum of the magnitudes of the truncated coefficients. TARP uses the first 4, 4, and 5 terms of these equations, respectively. With the shortened equations, only G and L are evaluated.

Then compute the solar declination angle, equation of time, and the earth-sun distance.

$$\delta = \arcsin(\theta / \sqrt{\rho}) \quad (B.5.4a)$$

$$\epsilon = -\arcsin(\phi / \sqrt{\rho - \theta^2}) / 15. \quad [\text{hours}] \quad (B.5.4b)$$

$$R = \sqrt{\rho} \quad (\text{B.5.4c})$$

The hour angle, H, is the number of hours from solar noon.

$$H = 15 (12 - t_g - \epsilon - \text{TZ}) + \text{LONG} \quad (\text{B.5.5})$$

where

t_g = standard time (hours) at midpoint of the timestep
 TZ = time zone number (1.3.4)
 LONG = longitude (1.3.3)

The solar direction cosines can be determined from these values plus the latitude, λ (north positive, south negative), of the site.

$$\text{CS}_1 = \cos\delta \sin H \quad (\text{B.5.6a})$$

$$\text{CS}_2 = \sin\delta \cos\lambda - \cos\delta \sin\lambda \cos H \quad (\text{B.5.6b})$$

$$\text{CS}_3 = \sin\delta \sin\lambda + \cos\delta \cos\lambda \cos H \quad (\text{B.5.6c})$$

CS_3 is the cosine of the solar zenith angle which also equals the sine of the solar altitude angle. The solar azimuth angle, ψ (relative to north), can be determined from

$$\sin \psi = \text{CS}_1 / \sqrt{1 - \text{CS}_3^2} \quad (\text{B.5.7a})$$

$$\cos \psi = \text{CS}_2 / \sqrt{1 - \text{CS}_3^2} \quad (\text{B.5.7b})$$

These angle calculations apply for the northern and southern hemispheres.

III.B.5.2 SOLAR INTENSITY

The calculation of direct normal solar intensity, I_b , and diffuse solar intensity, I_s , for clear design days is exactly as described in [7].

$$I_b = A e^{-B/\text{CS}_3} \quad (\text{B.5.8a})$$

$$I_s = C * I_b \quad (\text{B.5.8b})$$

The values of A, B, and C are calculated by a truncated Fourier series fit to the data in Table 1 of [7]. Seasonal effects implicit in that table would not apply to the southern hemisphere. When the clearness number is less than 0.75, it is assumed to represent the ratio k_T defined as

$$k_T = I / I_0 \quad (\text{B.5.9})$$

where

I = the total solar radiation on a horizontal surface

$$(= I_b * \text{CS}_3 + I_s)$$

I_0 = the solar radiation on a horizontal surface above the earth's atmosphere [= $(I_{sc}/R^2)*CS_3$]
 I_{sc} = the solar constant (1353 W/m²)

On such cloudy design days the following correlation [9] is used.

$$I_s/I = \begin{matrix} 1.0 - 0.249 k_T & k_T < 0.35 \\ 1.557 - 1.84 k_T & 0.35 < k_T < 0.75 \\ 0.177 & k_T > 0.75 \end{matrix} \quad (B.5.10)$$

Weather tape data is used by means of the BLAST program weather file processor. For transportability, a version of this processor should be incorporated into TARP. This version should include the most current solar radiation correlations.

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III.C TRANSIENT HEAT CONDUCTION

III.C.1 USE OF CONDUCTION TRANSFER FUNCTIONS

The conventional equation for calculating steady state heat flux from the inside to the outside of a wall is

$$KO = U * (TI - TO) \quad (C.1.1)$$

This equation is valid only when the wall is non-massive or when the inside or outside temperatures are constant in time. In the more common and complex situation where transient effects cannot be safely ignored, heat conduction calculations which properly account for the dynamic effects must be utilized. The methodology implemented in TARP is based on the standard response factor technique [1] developed by Stephenson and Mitalas [2] and Kusuda [3] modified for efficiency according to a suggestion by Peavy [4]. The modified response factors are called "conduction transfer functions" (CTF). The heat conduction at (and toward) the inside surface at time t is given by:

$$KI_t = \sum_{m=0}^{NT} Y_m * TO_{t-m} - \sum_{m=0}^{NT} Z_m * TI_{t-m} + \sum_{k=1}^{NF} J_k * KI_{t-k} \quad (C.1.2)$$

The heat conduction flux at (and toward) the outside surface is

$$KO_t = \sum_{m=0}^{NT} Y_m * TI_{t-m} - \sum_{m=0}^{NT} X_m * TO_{t-m} + \sum_{k=1}^{NF} J_k * KO_{t-k} \quad (C.1.3)$$

TARP uses the convention that the X CTF refer to outside (or eXterior) surface temperatures, and that the Z CTF refer to inside (or Zone side) temperatures as in [1]. The opposite convention is often used in other programs.

The current inside and outside conductive fluxes are functions of the current inside and outside temperatures plus a factor containing the previous temperatures and fluxes. TARP initializes the temperature and flux histories by starting from a steady state and repeatedly calculating the building thermal performance for the first day of the simulation period until essentially equal results are achieved. Equation (C.1.2) can be rewritten to emphasize the unknown values at time t .

$$KI_t = Y_0 * TO_t - Z_0 * TI_t + KIP_t \quad (C.1.4)$$

where

$$KIP_t = \sum_{m=1}^{NT} Y_m * TO_{t-m} - \sum_{m=1}^{NT} Z_m * TI_{t-m} + \sum_{k=1}^{NF} J_k * KI_{t-k} \quad (C.1.5)$$

Equation (C.1.3) may be similarly rewritten.

$$KO_t = Y_0 * TI_t - X_0 * TO_t + KOP_t \quad (C.1.6)$$

where

$$KOP_t = \sum_{m=1}^{NT} Y_m * TI_{t-m} - \sum_{m=1}^{NT} X_m * TO_{t-m} + \sum_{k=1}^{NF} J_k * KO_{t-k} \quad (C.1.7)$$

For lightweight surfaces, such as sheet metal or thin glass, there are no CTF terms for $m > 1$ or $k > 0$. In that case $X_0 = Y_0 = Z_0 = U$, and equations (C.1.4) and (C.1.6) both reduce to equation (C.1.1). Air cavities are handled by massless 'slabs' which have only thermal resistance. This resistance cannot be described as temperature dependent. The conductive properties of a multi-pane window are described in this manner and appropriate conduction transfer functions are computed.

III.C.2 CALCULATION OF CONDUCTION TRANSFER FUNCTIONS

The CTF method is based upon the exact solution of a triangular temperature pulse on either side of the wall. A series of triangular temperature pulses can be superposed to produce a good approximation of a continuous temperature function. The triangular pulse is solved by a Laplace transform. TARP follows the calculation technique used in BLAST [5] and described in detail by Hittle [6]. That description is quite lengthy and is not repeated here.

One useful property of the CTF is that the steady state conductance of the wall is related to the CTF by

$$\begin{aligned} U &= \sum_{m=0}^{NT} X_m / (1 - \sum_{k=1}^{NF} J_k) \\ &= \sum_{m=0}^{NT} Y_m / (1 - \sum_{k=1}^{NF} J_k) \\ &= \sum_{m=0}^{NT} Z_m / (1 - \sum_{j=1}^{NF} J_k) \end{aligned} \quad (C.2.1)$$

This provides the method for determining the number of CTF terms to produce the desired accuracy.

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III.D WINDOW OPTICS

Windows are thermally critical elements of the building envelope. They are difficult to insulate and produce much greater conductive gains and losses than corresponding wall areas. Most can be opened to provide ventilation, but then they are significant sources of infiltration. The unique characteristic of windows is the transmission of light (short wavelength thermal radiation) directly into the building. This transmitted light is usually a desirable heat gain in the winter and an undesirable gain in the summer. It also provides natural lighting inside the building. The following sections describe the TARP optical algorithms.

III.D.1 OPTICAL COEFFICIENTS

Figure D.1 shows how the solar-optical properties of typical uncoated glazing materials vary with the incident angle of the light [1]. As the incident angle increases from $\theta = 0$ degrees (normal incidence), the transmittance decreases, reflectance increases, and absorptance first increases due to the lengthened optical path through the glass and then decreases as more incident radiation is reflected away. These properties also vary with the wavelength of the incident radiation. The total solar radiation incident on a window (Q) is composed of beam and diffuse components,

$$Q = I_b \cos \theta + I_d \quad (D.1.1)$$

The beam component (I_b) comes directly from the sun and is incident at angle θ . The diffuse component (I_d) comes uniformly from all directions. Some of the incident radiation is transmitted according to

$$Q_T = T_b * I_b * \cos \theta + T_d * I_d \quad (D.1.2)$$

where

T_b is the beam transmittance at θ and

T_d is the transmittance for diffuse radiation.

Some is absorbed according to

$$Q_A = A_b * I_b * \cos \theta + A_d * I_d \quad (D.1.3)$$

where A_b and A_d are the beam and diffuse absorptances. If an internal shade is present, it also absorbs radiation with absorptances AS_b and AS_d .

$$Q_S = AS_b * I_b * \cos \theta + AS_d * I_d \quad (D.1.4)$$

The energy absorbed in the shade is convected directly to the room air. The energy absorbed in the glass is convected both into the room and to the outside according to proportions (neglecting the thermal resistance of the glass which is small compared to H_i and H_o) defined by

$$QA_{in} = QA * HI / (HI + HO) \quad (D.1.5a)$$

and

$$QA_{out} = QA * HO / (HI + HO) \quad (D.1.5b)$$

where

HI = inside surface heat transfer coefficient and
HO = outside surface heat transfer coefficient.

The expressions become more complicated for a two pane window.

$$QA_{in} = QAI * (U/HO + U/HS) + QAO * U/HO \quad (D.1.6a)$$

and

$$QA_{out} = QAI * U/HI + QAO * (U/HI + U/HS) \quad (D.1.6b)$$

where

$U = 1 / (1/HO + 1/HS + 1/HI)$,
HS = heat transfer coefficient of the air gap,
QAI = energy absorbed in the outer pane and
QAO = energy absorbed in the outer pane.

In TARP a consistent description of absorption in single and multi pane windows is achieved by separating QA into equal components, QAI and QAO, for the single pane window. HS is then the U-value of the glass. The actual distribution of the QAI and QAO is handled by the more general surface heat balance equations (I.3.2) and (J.3.2).

The angle dependent properties of T_d , AO_d , AI_d , and AS_d are represented by polynomial equations in terms of $\cos\theta$. Two ranges of $\cos\theta$ are used for greater accuracy, so each property (X) has two equations

$$X = c_0 + c_1\cos\theta + c_2(\cos\theta)^2 + \dots + c_4(\cos\theta)^4 \quad [\cos\theta > 0.5] \quad (D.1.7a)$$

and

$$X = d_1\cos\theta + d_2(\cos\theta)^2 + \dots + d_6(\cos\theta)^6 \quad [\cos\theta < 0.5] \quad (D.1.7b)$$

The coefficients c_1 and d_1 are determined by curve fits to optical values computed by methods described in the following sections. TARP also computes transmittance and absorptances for diffuse radiation.

III.D.2 SHADING COEFFICIENTS

The solar optical properties of windows are often described by a shading coefficient, SC, [2] which is defined as

$$SC = \frac{\text{Solar Heat Gain of Window}}{\text{Solar Heat Gain of Reference Glass}} \quad (D.2.1)$$

For single glazing this is

$$SC = \frac{[QT + QA*(HO+HI)/HO]}{[QT_{dsa} + QA_{dsa}*(HO+HI)/HO]} \quad (D.2.2)$$

where

QT = radiation transmitted
 QT_{dsa} = QT of DSA glass
 QA = radiation absorbed
 QA_{dsa} = QA of DSA glass
 HO = outside surface heat transfer coefficient (= 22.7 W/m²k)
 HI = inside surface heat transfer coefficient (= 8.3 W/m²K)

The reference glazing material is double-strength sheet glass (DSA) with 0.86 transmittance, 0.08 reflectance, and 0.06 absorptance at normal incidence.

A shading coefficient is implemented in TARP by multiplying SC times the c_1 and d_1 of (D.1.7) computed for the reference glass. This gives correct steady state solar gains, but does not give correct proportions of transmitted and absorbed radiation (especially for heat absorbing glasses). Correct proportions are necessary in dynamic simulation because the absorbed component produces an instantaneous convective gain to the space while the transmitted component is first absorbed by the surfaces of the space and produces a delayed gain. Therefore, the shading coefficient method is not recommended unless data for the following detailed method is unavailable.

III.D.3 UNCOATED PANE OPTICS

When a ray of light reaches a smooth interface between two non-conducting media, part of the ray is reflected and part is refracted as in figure D.2. The angle of reflection equals the angle of incidence (θ_1). The angle of refraction (θ_2) is given by Snell's law:

$$n_1 * \sin\theta_1 = n_2 * \sin\theta_2 \quad (D.3.1)$$

where n_1 and n_2 are the indexes of refraction of the two media. The refractive index of air is effectively equal to unity. The refractive index of glass is dependent on both the composition of the glass and the wavelength of the light. The variation is small for typical wavelengths between 0.3 and 3.0 microns, but it is enough for a glass prism to separate a ray of white light into the spectrum of colors.

Reflectance is the ratio of the energy reflected from the interface to the energy incident upon it. The electromagnetic description of light shows that reflectance depends on the polarization of the incident light. The two components of polarization are perpendicular to the plane of incidence (also called transverse electric or TE) and parallel to the plane of incidence (called transverse magnetic or TM). A simple formula [3] for reflectance at the interface shown in figure D.2 is

$$\rho = [(p_1 - p_2)/(p_1 + p_2)]^2 \quad (D.3.2)$$

$$p_i = \cos\theta_i * n_i \quad \text{for TE light} \quad (D.3.2a)$$

and

$$p_i = \cos\theta_i / n_i \quad \text{for TM light} \quad (D.3.2b)$$

Unpolarized light may be considered to consist of one half TE and one half TM polarized light. (D.3.2) is a computationally simpler form of the more familiar Fresnel equations.

The fraction of light transmitted through the interface is given by

$$\tau = (p_2/p_1) * [2 * p_1 / (p_1 + p_2)]^2 \quad (D.3.3)$$

with the same polarization dependent values for p as above. It is easier to calculate transmittance from the simple energy balance: $\tau = 1 - \rho$.

Glass absorbs light passing through it in proportion to the intensity of the light. The fraction of light (τ_g) transmitted through a given distance (x) of glass is given by the exponential decay formula

$$\tau_g = e^{-kx} \quad (D.3.4)$$

where k is the extinction coefficient of the glass. The value of k is wavelength dependent but independent of polarization. The fraction of light absorbed is $a_g = 1 - \tau_g$. For a glass plate of thickness L , the distance the light travels in passing from one side to the other is $x = L / \cos\theta_2$. Therefore,

$$\tau_g = e^{-kL/\cos\theta_2} \quad (D.3.5)$$

A ray of light incident on a sheet of glass will be both reflected and refracted at the front surface. Part of the refracted component will be absorbed in the glass before reaching the back surface where it is again reflected and refracted. This continues until all the light is either absorbed or escapes from the front or back surfaces of the glass. Figure D.3 shows the first several reflections of the incident light ray. Summation of the transmitted, reflected, and absorbed components of the incident ray give the total transmittance (t), reflectance (r), and absorptance (a) of the sheet of glass. These values must be determined separately for both polarization components. ρ , τ ($= 1 - \rho$), τ_g , and α_g ($= 1 - \tau_g$) are functions of the angle of incidence and wavelength of the light. They are identical at both sides of the glass.

Single pane transmittance:

$$\begin{aligned} t &= (1-\rho)^2 \tau_g + (1-\rho)^2 \rho^2 \tau_g^3 + (1-\rho)^2 \rho^4 \tau_g^5 + \dots \\ &= (1-\rho)^2 \tau_g (1 + \rho^2 \tau_g^2 + \rho^4 \tau_g^4 + \dots) \\ &= \tau^2 \tau_g / (1 - \rho^2 \tau_g^2) \end{aligned} \quad (D.3.6)$$

Single pane reflectance:

$$\begin{aligned}
 r &= \rho + (1-\rho)^2 \rho \tau_g^2 + (1-\rho)^2 \rho^3 \tau_g^4 + \dots \\
 &= \rho + (1-\rho) 2 \rho \tau_g^2 (1 + \rho^2 \tau_g^2 + \rho^4 \tau_g^4 + \dots) \\
 &= \rho + \tau_g^2 \rho \tau_g^2 / (1 - \rho^2 \tau_g^2)
 \end{aligned} \tag{D.3.7}$$

Single pane absorptance:

$$\begin{aligned}
 a &= [(1-\rho)-(1-\rho)\tau_g] + [(1-\rho)\rho\tau_g-(1-\rho)\rho\tau_g^2] + [(1-\rho)\rho^2\tau_g^2-(1-\rho)\rho^2\tau_g^3] + \dots \\
 &= (1-\rho)(1-\tau_g)(1 + \rho\tau_g + \rho^2\tau_g^2 + \dots) \\
 &= \tau_g \alpha_g / (1 - \rho \tau_g)
 \end{aligned} \tag{D.3.8}$$

The energy balance ($t + r + a = 1$) allows any one of the three components to be computed from the other two, or it allows a check for the consistency of all three.

The extinction coefficient of a pane of glass can be computed from the thickness, normal incidence transmittance, and index of refraction. At normal incidence

$$\rho = [(n_1 - n_2)/(n_1 + n_2)]^2 \tag{D.3.9a}$$

$$= [(n - 1)/(n + 1)]^2 \text{ for air and glass}$$

and

$$t = [(1 - \rho)^2 \tau_g] / [1 - \rho^2 \tau_g^2] \tag{D.3.9b}$$

which combine to give a quadratic equation for τ_g . The solution of that equation is

$$\tau_g = (-B + \sqrt{B^2 + 4C}) / 2 \tag{D.3.10}$$

where $B = (1-\rho)^2/(\rho^2 t)$ and $C = 1/\rho^2$. Finally, from (D.3.5)

$$k = -\ln(\tau_g) / L \tag{D.3.11}$$

This provides a means of describing the glass pane in terms of simply measurable optical properties and makes it unnecessary to use the less exact shading coefficients when those properties are known.

III.D.4 REFLECTIVE COATINGS

A metallic film will be treated as a thin, smooth coating on one side of the pane of glass. Let medium 1 be the air, medium 2 the film, and medium 3 the glass substrate. The mathematical treatment of the optics of a metallic film [4, 5] is based on the index of refraction of the metal being a complex number (complex numbers indicated by \sim)

$$\tilde{n}_2 = n_2 - ik_2 \quad [i = \sqrt{-1}] \quad (D.4.1)$$

where n_2 is the (real) index of refraction and k_2 is the extinction coefficient.

Snell's law still applies, but it leads to a complex value of $\cos \tilde{\theta}_2 = x + iy$. Let

$$c = [(n_1 \sin \theta_1 n_2) / (n_2^2 + k_2^2)]^2 \quad (D.4.2a)$$

and

$$d = [(n_1 \sin \theta_1 k_2) / (n_2^2 + k_2^2)]^2 \quad (D.4.2b)$$

Then

$$x = \sqrt{1 - c + d + \sqrt{(1 - c + d)^2 + 4 * c * d}} / 2 \quad (D.4.2c)$$

and

$$y = c * k_2 / (x * n_2) \quad (D.4.2d)$$

The amplitude (not energy) reflectance at the interface between media i and j for light incident from medium i is given by

$$\tilde{\rho}_{ij} = (\tilde{p}_i - \tilde{p}_j) / (\tilde{p}_i + \tilde{p}_j) \quad (D.4.3a)$$

where

$$\tilde{p}_i = \cos \tilde{\theta}_i * \tilde{n}_i \quad [\text{TE polarization}] \quad (D.4.3b)$$

$$\tilde{p}_i = \tilde{n}_i / \cos \tilde{\theta}_i \quad [\text{TM polarization}] \quad (D.4.3c)$$

The amplitude transmittance at an interface is given by

$$\tilde{\tau}_{ij} = 2 * \tilde{p}_i / (\tilde{p}_i + \tilde{p}_j) \quad (D.4.3d)$$

Note that $\tilde{\rho}_{ji} = -\tilde{\rho}_{ij}$ and $\tilde{\tau}_{ij} * \tilde{\tau}_{ji} = 1 - \tilde{\rho}_{ij}^2$.

Amplitude transmittance ($\tilde{\tau}_f$) within the metallic film is based on its phase thickness defined as

$$\tilde{d} = 2 * \pi * D * \tilde{n}_2 * \cos \tilde{\theta}_2 / \lambda \quad (D.4.4a)$$

where

D = thickness of the film and

λ = wavelength of the light

so that

$$\tilde{\tau}_f = e^{-i\tilde{d}} \quad [i = \sqrt{-1}] \quad (D.4.4b)$$

Considerations of multiple reflections within the film leads to expressions for the total amplitude reflectance and transmittance. For light incident from medium i the expressions are

$$\tilde{\rho}_{13} = (\tilde{\rho}_{12} + \tilde{\rho}_{23} * \tilde{\tau}_f^2) / (1 + \tilde{\rho}_{12} * \tilde{\rho}_{23} * \tilde{\tau}_f^2) \quad (D.4.6a)$$

and

$$\tilde{\tau}_{13} = \tilde{\tau}_{12} * \tilde{\tau}_{23} * \tilde{\tau}_f / (1 + \tilde{\rho}_{12} * \tilde{\rho}_{23} * \tilde{\tau}_f^2) \quad (\text{D.4.6b})$$

Reverse the subscripts for light incident from medium 3.

The energy reflectance and transmittance are given by

$$\rho_{13} = \tilde{\rho}_{13} * \bar{\rho}_{13} \quad (\text{D.4.7a})$$

and

$$\tau_{13} = \tilde{\tau}_{13} * \bar{\tau}_{13} * \tilde{p}_3 / \tilde{p}_1 \quad (\text{D.4.7b})$$

where \bar{p} and $\bar{\tau}$ are the complex conjugates of \tilde{p} and $\tilde{\tau}$. Energy is absorbed in the metallic film ($\rho_{13} + \tau_{13} < 1$).

Most of the above expression are complex. Rather than expanding them to get solutions in terms of real numbers, it is easier to let the computer evaluate the expressions by using complex arithmetic.

Coated glass has the same multiple reflection property as uncoated glass. Derivation of the total reflectance, transmittance, and absorptance is complicated by the fact that reflectances at the coatings depend on the direction of incidence. Again consider a light ray incident from the left (as was done in figure D.3). Properties (ρ , τ) for both the left and right surfaces of the glass are dependent on whether the light is incident from the left or right. Consider the left side to be the "front" and the right side to be the "back" of the glass. The following subscripts specify these conditions:

- 1: light incident on the left side from the left
- 2: light incident on the left side from the right
- 3: light incident on right side from the right (none)
- 4: light incident on right side from the left

so that for light incident from the front (superscript f)

$$r^f = \rho_1 + \rho_4 \tau_1 \tau_2 \tau_g^2 / (1 - \rho_2 \rho_4 \tau_g^2) \quad (\text{D.4.8a})$$

and

$$t^f = \tau_1 \tau_4 \tau_g / (1 - \rho_2 \rho_4 \tau_g^2) \quad (\text{D.4.8b})$$

A simple exchange of subscripts (1:3 and 2:4) will give the expressions for light incident from the back (superscript b).

$$r^b = \rho_3 + \rho_2 \tau_3 \tau_4 \tau_g^2 / (1 - \rho_4 \rho_2 \tau_g^2) \quad (\text{D.4.9a})$$

and

$$t^b = \tau_3 \tau_2 \tau_g / (1 - \rho_4 \rho_2 \tau_g^2) \quad (\text{D.4.9b})$$

Since light is absorbed in the glass and in the coatings on either side, it is easiest to compute absorptance from the energy balance: $a = 1 - r - t$. If both sides of the glass are uncoated, $\rho_1 = \rho_2 = \rho_3 = \rho_4$, and $\tau_1 = \tau_2 = \tau_3 = \tau_4$ and equations (D.4.8a and b and D.4.9a and b) reduce to (D.3.7) and (D.3.6).

III.D.5 MULTI-PANE WINDOWS

The optical properties of a combination of two panes of glass can be determined from the properties of the component single panes. The values for the TE and TM polarization components must be determined separately and then added according to the relative proportions of each component [6].

Figure D.4 shows two panes of glass with fluxes of light going to both the right (I) and to the left (J). The radiation fluxes are made up of all transmitted and inter-reflected components. Let

t_n = transmittance of pane n (as an individual pane)

a_n^f = absorptance of pane n for flux from left (front)

a_n^b = absorptance of pane n for flux from right (back)

r_n^f = reflectance of pane n for light from the left (front)

r_n^b = reflectance of pane n for light from the right (back)

then

$$J_1 = I_1 * r_2^f + J_2 * t_2 \quad (D.5.1a)$$

$$J_0 = I_0 * r_1^f + J_1 * t_1 \quad (D.5.1b)$$

$$I_2 = I_1 * t_2 + J_2 * r_2^b \quad (D.5.1c)$$

$$I_1 = I_0 * t_1 + J_1 * r_1^b \quad (D.5.1d)$$

The optical properties for light incident only from the front are given by setting $J_2 = 0$, and substituting (D.5.1a-d) into the following definitions.

$$\begin{aligned} T^f &= I_2 / I_0 \\ &= B * t_2 \end{aligned} \quad (D.5.2a)$$

$$\begin{aligned} R^f &= J_0 / I_0 \\ &= r_1^f + B * r_2^f * t_1 \end{aligned} \quad (D.5.2b)$$

$$\begin{aligned} A_1^f &= (a_1^f * I_0 + a_1^b * J_1) / I_0 \\ &= a_1^f + B * r_2^f * a_1^b \end{aligned} \quad (D.5.2c)$$

$$\begin{aligned} A_2^f &= a_2^f * I_1 / I_0 \\ &= B * a_2^f \end{aligned} \quad (D.5.2d)$$

where

$$B = t_1 / (1 - r_1^b * r_2^f) \quad (D.5.2e)$$

For light incident from the back, set $I_0 = 0$, to obtain

$$T^b = J_0 / J_2 = C * t_1 \quad (D.5.3a)$$

$$R^b = I_2 / J_2 = r_2^b + C * r_1^b * t_2 \quad (D.5.3b)$$

$$A_2^b = (a_2^b * J_2 + a_2^f * I_1) / J_2 = a_2^b + C * r_1^b * a_2^f \quad (D.5.3c)$$

$$A_1^b = a_1^b * J_1 / J_2 = C * a_1^b \quad (D.5.3d)$$

where

$$C = t_2 / (1 - r_2^f * r_1^b) \quad (D.5.3e)$$

Note that $T^f = T^b$. All other front and back coefficients may be different.

Similar heat balances can be set up for triple glazing. They lead to the following equations for front radiation.

$$T^f = E * D * t_3 \quad (D.5.4a)$$

$$R^f = r_1^f + E * t_1 * (r_2^f + D * r_3^f * t_2) \quad (D.5.4b)$$

$$A_1^f = a_1^f + a_1^b * E * (r_2^f + D * r_3^f * t_2) \quad (D.5.4c)$$

$$A_2^f = E * (a_2^f + a_2^b * D * r_3^f) \quad (D.5.4d)$$

$$A_3^f = a_3^f * E * D \quad (D.5.4e)$$

where

$$D = t_2 / (1 - r_2^b * r_3^f) \quad (D.5.4f)$$

and

$$E = t_1 / (1 - r_1^b * r_2^f - D * r_1^b * r_3^f * t_2) \quad (D.5.4g)$$

There is a similar set of equations for radiation incident from the back. TARP also uses expressions for quadruple glazing, which are not repeated here.

III.D.6 DIFFUSE RADIATION

Diffuse radiation is considered to be of uniform intensity from all directions and to be unpolarized (equal amounts of TE and TM polarizations). Consider a small area, dA_1 , under a hemisphere of uniform brightness I (figure D.5). The energy received is given by [7]

$$dQ = I dA_1 \cos\theta d\Omega \quad (D.6.1)$$

where

dQ / dA_1 = energy per unit area

$d\Omega$ = the differential solid angle = dA_2 / r^2

$$= 2 \pi (r \sin\theta) r d\theta / r^2$$

Let $X(\theta)$ be the transmittance, reflectance, or absorptance for beam radiation of a system of glass panes. Then the diffuse property, X_d , is given by

$$X_d = \frac{\int_0^{\pi/2} X(\theta) 2 \pi I \sin\theta \cos\theta d\theta}{\int_0^{\pi/2} 2 \pi I \sin\theta \cos\theta d\theta} \quad (D.6.2)$$

The integral is evaluated by Simpson's method using beam values of $X(\theta)$ at appropriate θ .

III.D.7 INTERIOR SHADING DEVICES

Windows commonly have drapes or blinds in addition to the panes of glass discussed so far. In TARP such interior shading devices are modeled as diffusely transmitting (t_s), reflecting (r_s) and absorbing (a_s) surfaces. When an interior shading device is added to the glazing system, a new set of inter-reflected components is created (figure D.6). The total forward flux on the shade is $I_s (= I_0 * T_f^f + J_s * R_d^b)$. Note that we are interested in the diffuse back reflectance of the panes of glass. The total (diffusely) transmitted flux through the shade is $I_t = I_s * t_s$. The total leftward flux is $J_s = I_s * r_s$. Therefore, $I_s = I_0 * T_f^f / (1 - r_s * R_d^b)$, and the total transmitted flux is

$$I_t = I_0 * T_f^f * t_s / (1 - r_s * R_d^b) \quad (D.7.1)$$

The total shade absorptance is

$$A_s = I_s * a_s / I_0 = T_f^f * t_s * a_s / (1 - r_s * R_d^b) \quad (D.7.2)$$

The total forward absorptance of each pane of glass is modified by

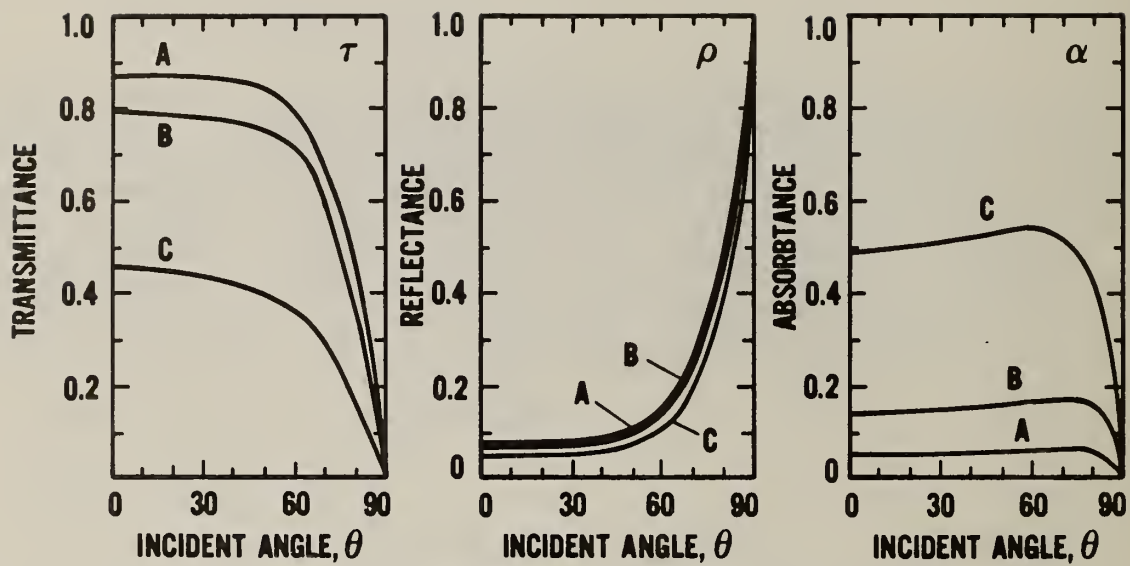
$$\begin{aligned} A_n^f &= A_n^f + J_s * A_{nd}^b \\ &= A_n^f + A_{nd}^b * T_f^f * r_s / (1 - r_s * R_d^b) \end{aligned} \quad (D.7.3)$$

Thus in the evaluation of the optical properties of a pane/shade system, it is first necessary to compute the diffuse back absorptance of each pane in the glass system by integrating beam A_n^b over θ . Then the pane/shade beam transmittance and absorptances are computed at the angles to be used in the optical properties curve fits. Finally the pane/shade diffuse properties can be computed.

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- [6] Hottel, H. C., and Sarofim, A. F., Radiative Transfer, (McGraw-Hill, 1967), p 197, fig 5-12.
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A = DSA glass
 B = 6mm (0.25 in) clear glass
 C = 6mm (0.25 in) heat absorbing glass

Figure III.D.1 Variation of solar-optical properties with angle of incidence

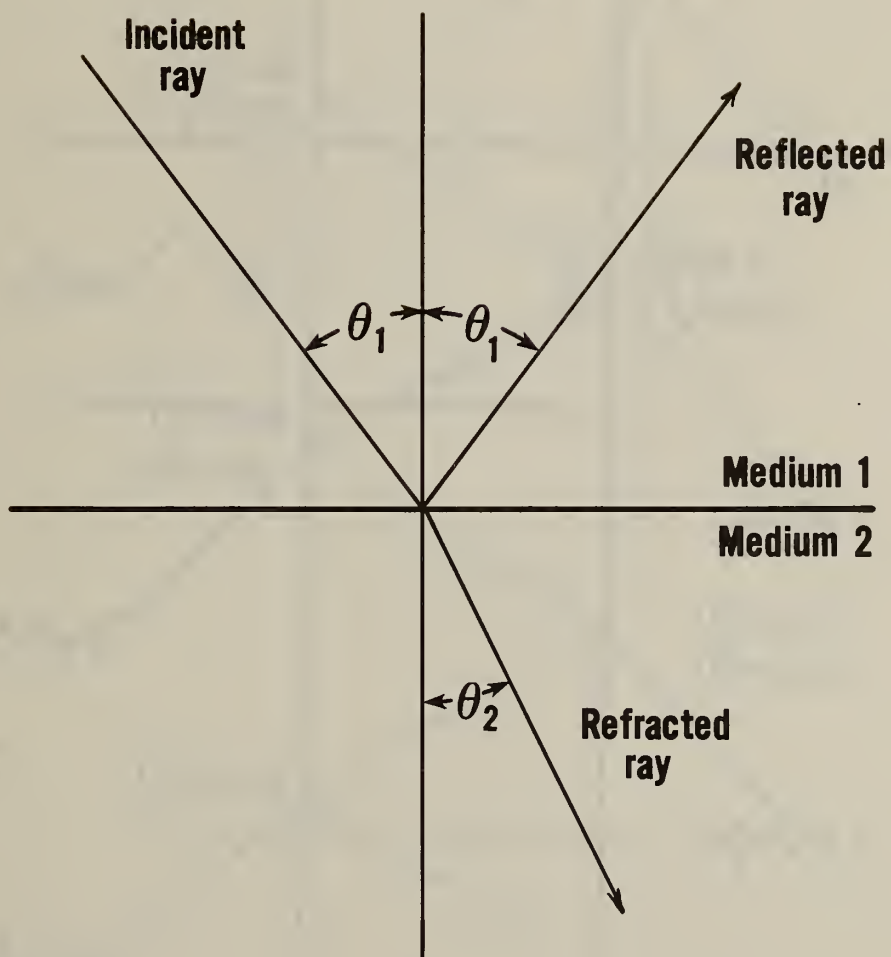


Figure III.D.2 Reflection and refraction at an interface

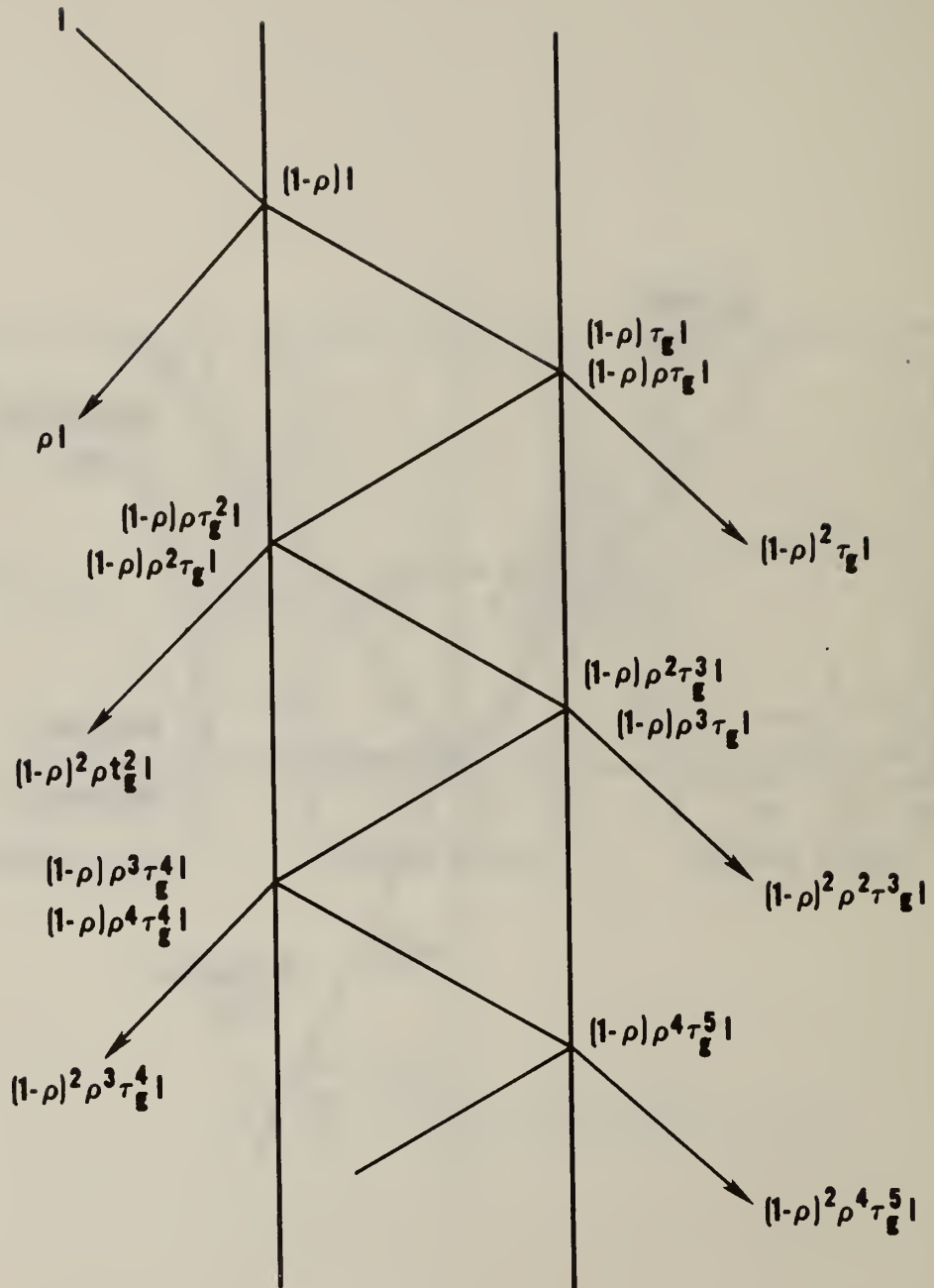


Figure III.D.3 Multiple reflections in a pane of glass

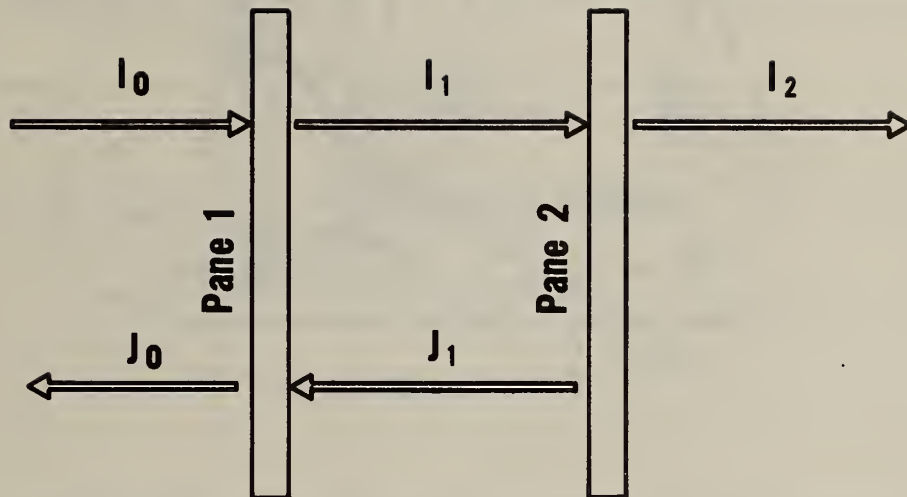


Figure III.D.4 Two-pane window system

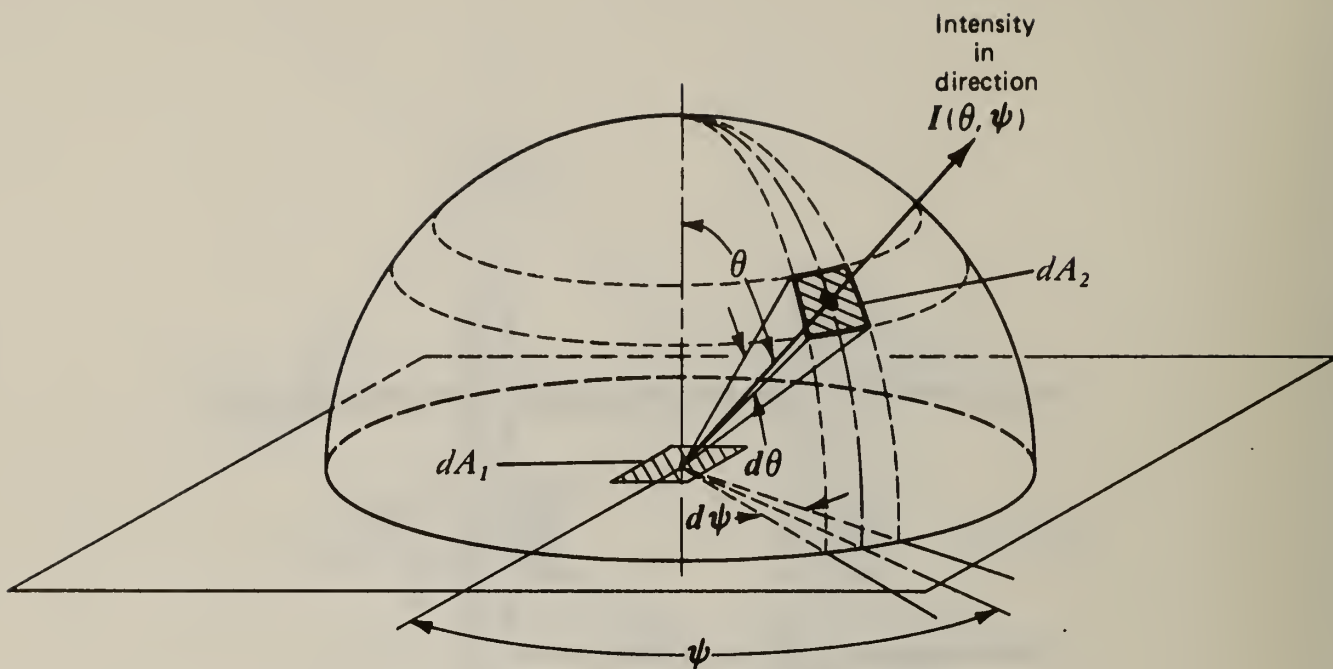


Figure III.D.5 Coordinate system for diffuse radiation

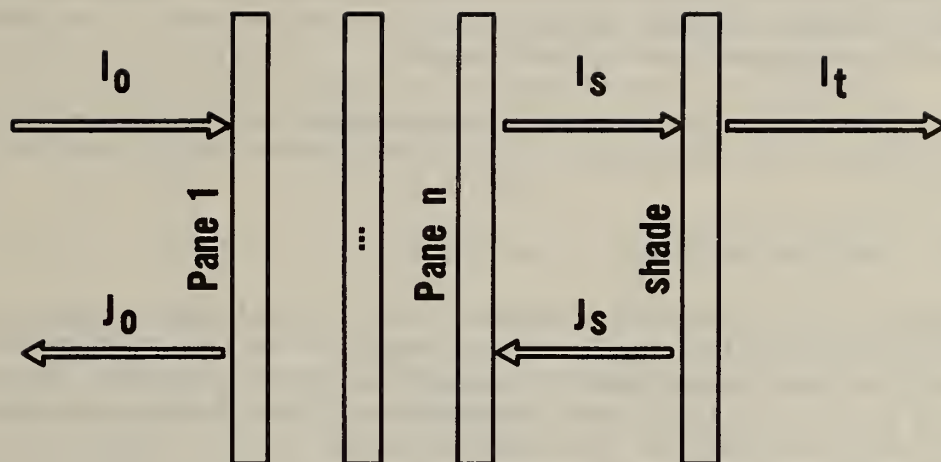


Figure III.D.6 Window system with interior shade

III.E SOLAR GAINS AND SHADOWING

When assessing heat gains in buildings due to solar radiation, it is necessary to know how much of each part of the building is shaded and how much is in direct sunlight. As an example, figure E.1 shows a flat roofed, L-shaped structure with a window in each of the visible sides. The sun is to the right so that walls 1 and 3 and windows a and c are completely shaded, and wall 4 and window d are completely sunlit. Wall 2 and window b are partially shaded. The sunlit area of each surface changes as the position of the sun changes during the day. The purpose of the TARP shadow algorithm is to compute such sunlit areas.

The shadow algorithm is based on coordinate transformation methods similar to Groth and Lokmanhekim [1] and the shadow overlap method of Walton [2].

III.E.1 SURFACE GEOMETRY

Shadow calculations first require that the building surfaces be described geometrically. Surfaces are described by the coordinates of their vertices in a three dimensional Cartesian coordinate system. This "global" coordinate system has the X-axis pointing east, the Y-axis pointing north, and the Z-axis pointing up. The azimuth angle (ψ) of a surface is the angle from the north axis to the projection onto the X-Y plane of a normal to the surface (clockwise positive). The surface tilt angle (ϕ) is the angle between the Z-axis and the normal to the surface. The vertices are recorded in counter-clockwise sequence (as the surface is viewed from outside its zone).

TARP input allows the user to specify a rotation of ψ_b degrees of the "building" coordinate system from the global coordinate system. The global coordinates of zone origins are related to the building relative coordinates by

$$X_{zo} = X_{br} * \cos\psi_b - Y_{br} * \sin\psi_b \quad (E.1.1a)$$

$$Y_{zo} = X_{br} * \sin\psi_b + Y_{br} * \cos\psi_b \quad (E.1.1b)$$

$$Z_{zo} = Z_{br} \quad (E.1.1c)$$

The user is also permitted to rotate a zone ψ_z degrees relative to the building coordinate system. Origins of zone surfaces are then given relative to the zone coordinate system. The global coordinates of the surface origins are given by

$$X_{so} = X_{zo} + X_{zr} * \cos\psi_z - Y_{zr} * \sin\psi_z \quad (E.1.2a)$$

$$Y_{so} = Y_{zo} + X_{zr} * \sin\psi_z + Y_{zr} * \cos\psi_z \quad (E.1.2b)$$

$$Z_{so} = Z_{zo} + Z_{zr} \quad (E.1.2c)$$

A surface azimuth angle relative to the zone coordinate system (ψ_s) is converted to a global azimuth by

$$\psi = \psi_s + \psi_z + \psi_b \quad (E.1.3)$$

The surface tilt angle (ϕ) is not changed by these rotations about the Z-axis.

The coordinates of the surface vertices are given in a coordinate system in the plane of the surface relative to the second vertex as shown for four surfaces in figure E.2. The X-axis of the surface coordinate system is a horizontal line through the second vertex. The global coordinates of the surface vertices are given by

$$X = X_{so} - X_{sr} * \cos\psi - Y_{sr} * \sin\psi * \cos\phi \quad (E.1.4a)$$

$$Y = Y_{so} + X_{sr} * \sin\psi - Y_{sr} * \cos\psi * \cos\phi \quad (E.1.4b)$$

$$Z = Z_{so} + Y_{sr} * \sin\phi \quad (E.1.4c)$$

Vertices in the global coordinate system can be transformed to the coordinate system relative to a given surface by

$$X' = X - X_{so} \quad (E.1.5a)$$

$$Y' = Y - Y_{so} \quad (E.1.5b)$$

$$Z' = Z - Z_{so} \quad (E.1.5c)$$

$$X_{sr} = -X' * \cos\psi + Y' * \sin\psi \quad (E.1.5d)$$

$$Y_{sr} = -X' * \sin\psi * \cos\phi - Y' * \cos\psi * \cos\phi + Z' * \sin\phi \quad (E.1.5e)$$

$$Z_{sr} = X' * \sin\psi * \sin\phi + Y' * \cos\psi * \sin\phi + Z' * \cos\phi \quad (E.1.6f)$$

III.E.2 SHADOW PROJECTION

All architectural forms are represented by plane polygons. This can give good accuracy even for curved surfaces: a sphere can be approximated by the 20 nodes of an icosahedron with only 3 percent error in the shadow area cast by the sphere. Consider how a solid object, which is composed of a set of enclosing plane polygons, casts a shadow. Figure E.3 shows a box shaped structure on a horizontal surface. The structure consists of a top (surface 1) and four vertical surfaces (2 and 3 visible to the observer and 4 and 5 not visible). The sun is positioned behind and to the right of the structure and a shadow is cast onto the horizontal surface (the ground). Surfaces 1, 4, and 5 are in sunlight; 2 and 3 are in shade. It is possible to think of the structure's shadow as the combination of shadows cast by surfaces 1, 2, 3, 4 and 5 or by 1, 4 and 5, or by surfaces 2 and 3. This last combination of shadow casting surfaces is the simplest. In the TARP shadow algorithm every surface is considered to be one of the surfaces which

enclose a solid, and only those surfaces which are not sunlit at a given hour are considered shadowing surfaces.

The expressions in eq (E.1.6f) are the direction cosines of the surface:

$$CW_1 = \sin\psi * \sin\phi \quad (E.2.1a)$$

$$CW_2 = \cos\psi * \sin\phi \quad (E.2.1b)$$

$$CW_3 = \cos\phi \quad (E.2.1c)$$

The cosine of the angle of incidence of the sun's rays on the surface are given by the dot product of surface and sun (B.3.3) direction cosines.

$$\cos\theta = CS_1 * CW_1 + CS_2 * CW_2 + CS_3 * CW_3 \quad (E.2.2)$$

If $\cos\theta$ is less than zero, the sun is behind the surface.

A shadow is projected from the vertices of the shadowing surface (SS) along the direction of the sun's rays to the plane of the shadow receiving surface (RS). If any vertices of the SS are below the plane of the RS ($z < 0$), a false shadow is cast as in figure E.3. The "submerged" portion of the SS must be clipped off before projection. This is done by finding, through linear interpolation, the points on the perimeter of the SS which intersect the plane of the RS. These points become new vertices of the SS, which together with the other positive vertices define a clipped SS which casts only a real shadow.

A vertex located at (x, y, z) relative to the RS coordinate system casts a shadow to a point in the plane of the RS given by

$$x' = x - z * a / \cos\theta \quad (E.2.3a)$$

$$y' = y - z * b / \cos\theta \quad (E.2.3b)$$

where

$$a = \sin\psi * CS_1 - \cos\psi * CS_2$$

and

$$b = -\cos\psi * \cos\phi * CS_1 - \sin\psi * \cos\phi * CS_2 + \sin\phi * CS_3$$

III.E.3 HOMOGENEOUS COORDINATES

Two-dimensional homogeneous coordinate techniques are used to determine the vertices of shadow overlaps. In homogeneous coordinates, points and lines are represented by a single form which allows simple vector operations between those forms [3]. A point (X, Y) is represented by a three element vector (x, y, w) where $x = w*X$, $y = w*Y$, and w is any real number except zero. A line is also represented by a three element vector (a, b, c) . The directed line (a, b, c) from point (x_1, y_1, w_1) to point (x_2, y_2, w_2) is given by

$$(a, b, c) = (x_1, y_1, w_1) \text{ cross } (x_2, y_2, w_2) \quad (E.3.1)$$

The sequence in the cross product is a convention to determine sign. The condition that a point (x, y, w) lie on a line (a, b, c) is that

$$(a, b, c) \text{ dot } (x, y, w) = 0 \quad (\text{E.3.2})$$

Normalize the representation of a point by dividing by w . Then if

$$(a, b, c) \text{ dot } (x/w, y/w, 1) > 0 \quad (\text{E.3.3})$$

the point is to the left of the line, and if it is less than zero, the point is to the right of the line. The intercept (x, y, w) of line (a_1, b_1, c_1) and line (a_2, b_2, c_2) is given by

$$(x, y, w) = (a_1, b_1, c_1) \text{ cross } (a_2, b_2, c_2) \quad (\text{E.3.4})$$

Note that the use of homogeneous coordinates as outlined above provides a consistent method and notation for defining points and lines, for determining intercepts, and for determining whether a point lies to the left, to the right, or on a line. Normalization provides the means for transforming to and from homogeneous notation and Cartesian coordinates. Thus, if (X, Y) is a Cartesian coordinate pair, its homogeneous coordinates are $(X, Y, 1)$. Similarly, the homogeneous coordinates (x, y, w) can be transformed to the Cartesian point with coordinates $(x/w, y/w)$.

III.E.4 OVERLAPPING SHADOWS

After transforming the shadows onto the plane of the receiving surface, the basic job of the shadow algorithm is to determine the area of the overlap between the polygons representing the shadows and the polygon representing the receiving surface.

There is considerable simplification if only convex (no interior angle $> 180^\circ$) polygons are considered. The overlap between two convex polygons is another convex polygon. Coordinate and projection transformations of a convex polygon produce another convex polygon. Any non-convex polygon can be constructed as a sum of convex ones.

The vertices which define the overlap between two convex polygons, A and B, consist of:

- 1) the vertices of A enclosed by B,
- 2) the vertices of B enclosed by A,
- 3) and the intercepts of the sides of A with the sides of B.

In figure E.4a point a is the result of rule 1, point c is the result of rule 2, and points b and d result from rule 3. The overlap of A and B is the polygon a-b-c-d. Figure E.4b shows an overlap where all of the vertices of A are enclosed by B. Figure E.4c shows an overlap defined only by the intercepts of A and B. Figure E.4d shows a more complex overlap.

Coordinate transformation retains the order of the vertices of a polygon, while a projection reverses the order. The sequence of vertices of the receiving polygons should be reversed so it and all shadow polygons will have the same sequence.

A point is enclosed by a clockwise, convex polygon if it lies to the right of all sides (or does not lie to the left of any side) of the polygon. The intercept of two sides may not lie beyond the ends of either side. These are "line segments" rather than "lines". It is possible to tell if line segments A and B intercept within their end points by noting that the ends of A must lie on both sides of B, and the ends of B must lie on both sides of A as shown in figure E.5. This should be done before the intercept is calculated.

Once the vertices are determined, they must be sorted into clockwise order for the area to be computed. Given a plane polygon of n sequential vertices $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$, its area is given by [4]

$$A = (x_1y_2 + x_2y_3 + \dots + x_{n-1}y_n + x_ny_1 - y_1x_2 - y_2x_3 - \dots - y_nx_1)/2 \quad (E.4.1)$$

The area is positive if the vertices are counter-clockwise and negative if they are clockwise.

If two shadows overlap the receiving surface, they may also overlap each other as in figure E.6. The vertices of this overlap can be computed. The areas of all overlaps can be computed. The total sunlit area can be expressed as the sum of all polygon areas given a proper sign on each of the areas. The following convention was adopted:

receiving surface	positive (A)
overlap between shadow and receiving	negative (B & C)
overlap between two shadows	positive (D)

and so on through multiple overlaps where the sign of the overlap area is the product of the signs of the overlapping areas.

Partially transparent shadowing surfaces can also be modeled by giving a transparency (τ) to every shadowing polygon. Let τ of the receiving polygon be one. Then the τ of every overlap of polygons i and j is the product of τ_i and τ_j . The shaded area is then computed by summing $A_i * (1 - \tau_i)$ for all overlap polygons.

It is easy to determine the sunlit area of a window once all the shadow and overlap vertices on the wall have been computed. Consider wall 2 of figure E.1. First the wall is considered a simple rectangle and the window on it is ignored. The shadow overlapping is performed and the sunlit portion of the gross wall area is computed. Then the window rectangle is overlapped with the shadow to determine its sunlit area. The sunlit area of the window is subtracted from the gross wall sunlit area to determine the net wall sunlit

area. During this calculation it is not necessary to recompute the shadows, because they were precisely determined on the wall.

III.E.5 SOLAR GAINS

The total solar gain on any exterior surface is a combination of the absorption of direct and diffuse solar radiation given by

$$QSO = \alpha * (I_b * \cos\theta * S_s / S + I_s * F_{ss} + I_g * F_{sg}) \quad (E.5.1)$$

where

- α = solar absorptance of the surface
- θ = angle of incidence of the sun's rays
- S = area of the surface
- S_s = sunlit area
- I_b = intensity of beam (direct) radiation
- I_s = intensity of sky diffuse radiation
- I_g = intensity of ground reflected diffuse radiation
- F_{ss} = angle factor between the surface and the sky
- F_{sg} = angle factor between the surface and the ground

For the surface of a building located on a featureless plain

$$F_{ss} = (1 + \cos\phi) / 2 \quad (E.5.2a)$$

and

$$F_{sg} = (1 - \cos\phi) / 2 \quad (E.5.2b)$$

These values can be modified by the user.

For a window the absorptance, α , is divided into components α_b (for beam radiation) and α_d (for diffuse radiation) as described in section D. A similar expression describes the transmittance of solar radiation into the zone. In its default mode, TARP assumes that all transmitted beam radiation is incident on the floor. The floor absorbs a fraction of that radiation equal to the floor inside solar absorptance. The unabsorbed portion of the beam radiation is combined with the diffuse radiation and then evenly distributed over all surfaces as described in section F.2. In the detailed mode, TARP computes the beam radiation distribution on all surfaces.

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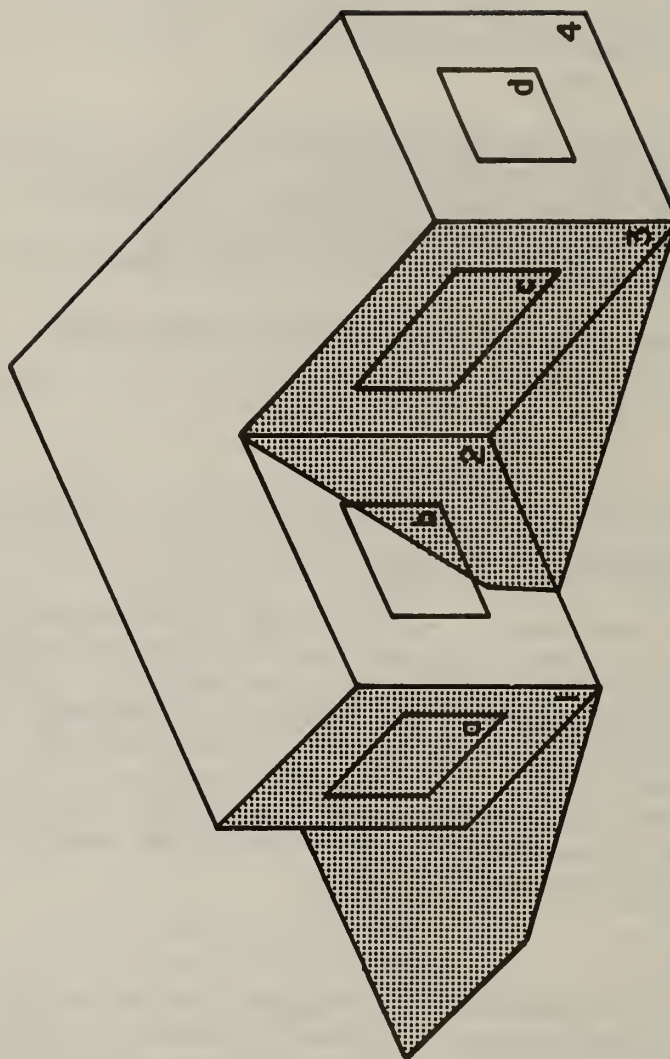


Figure III.E.1 Shadows on an L-shaped building

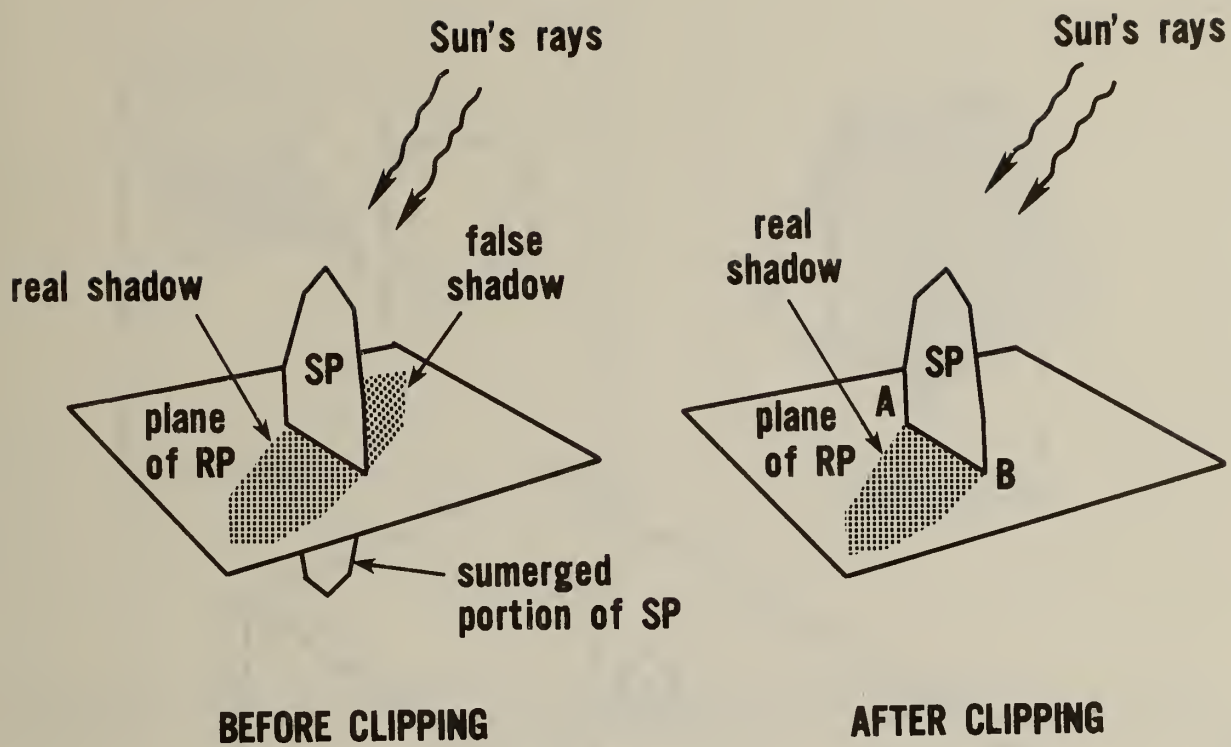


Figure III.E.2 Shadow polygon clipping

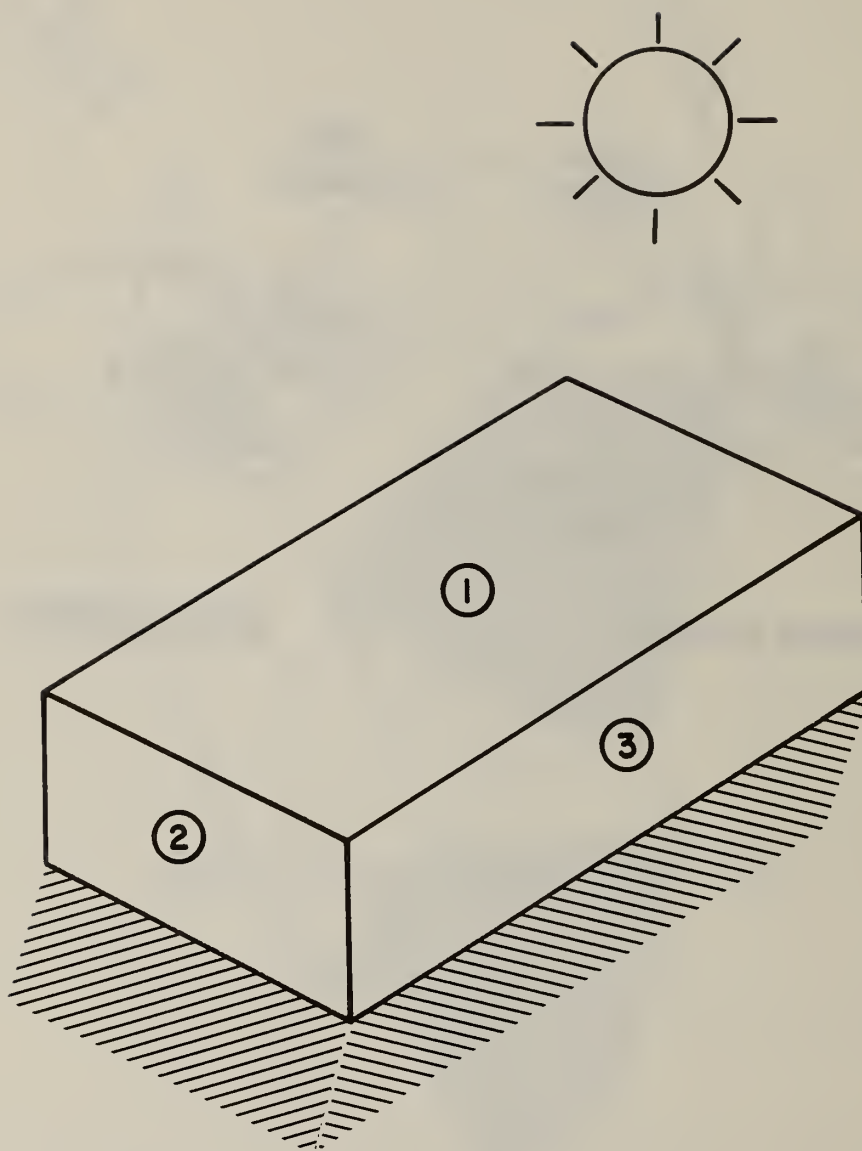
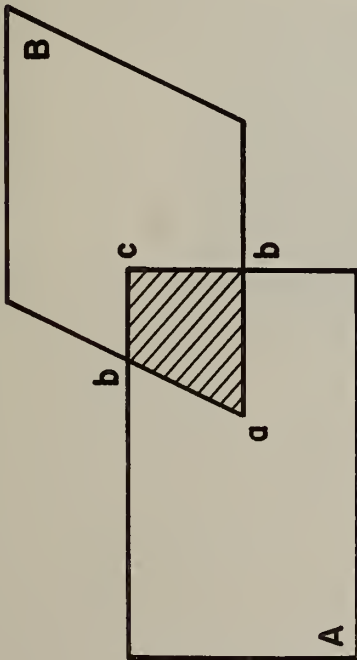
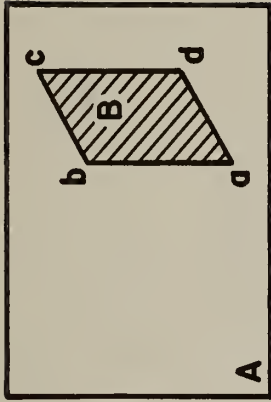


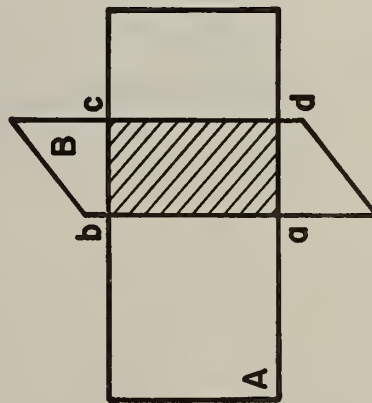
Figure III.E.3 Shadow casting surfaces



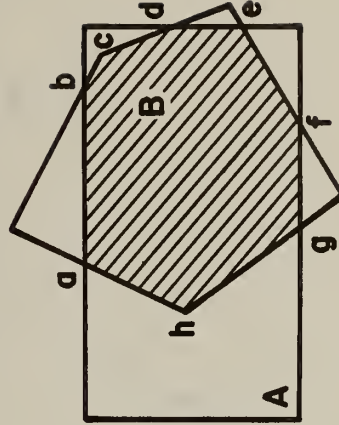
4a



4b



4c



4d

Figure III.E.4 Overlapping convex polygons

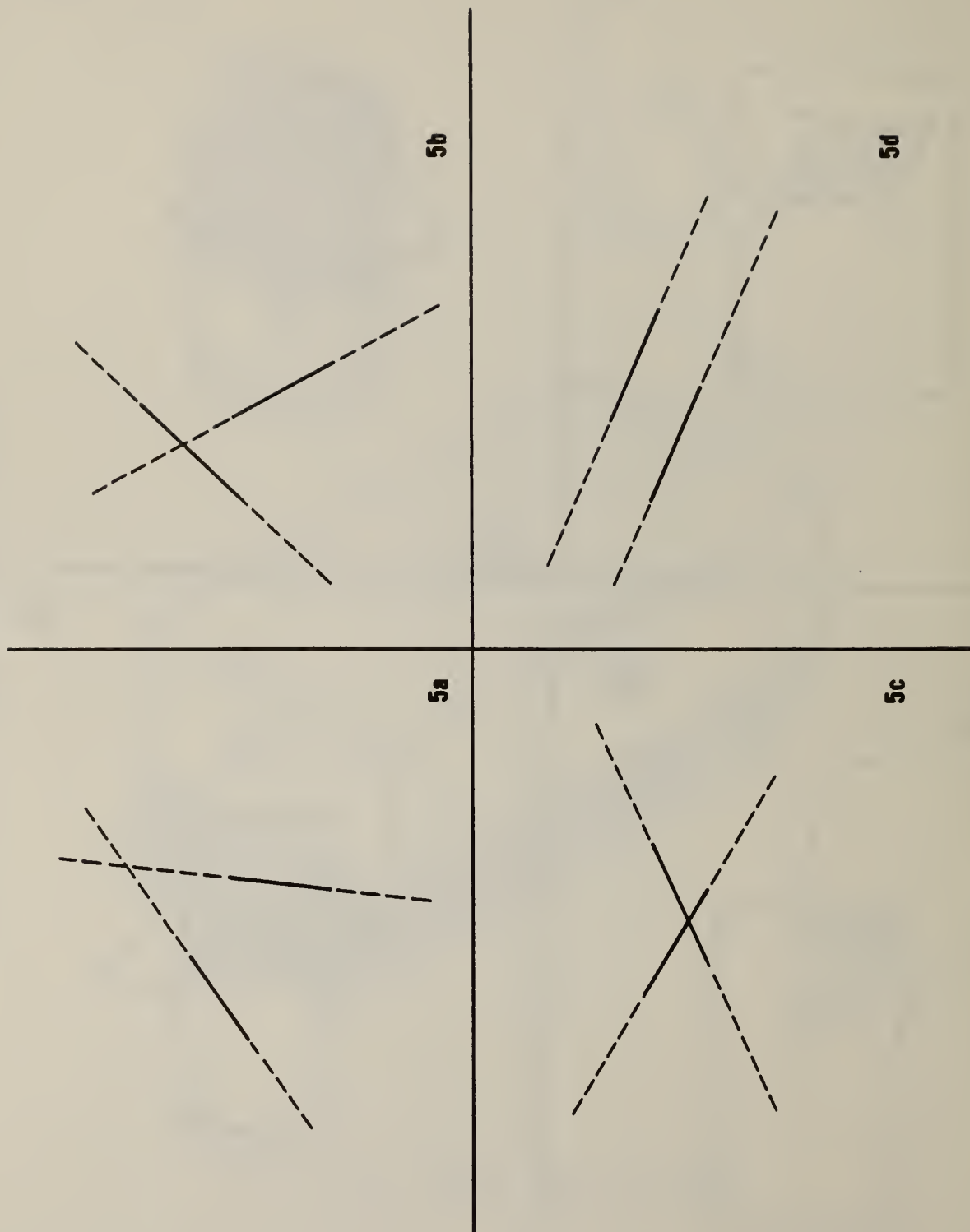


Figure III.E.5 Intercepts of line segments

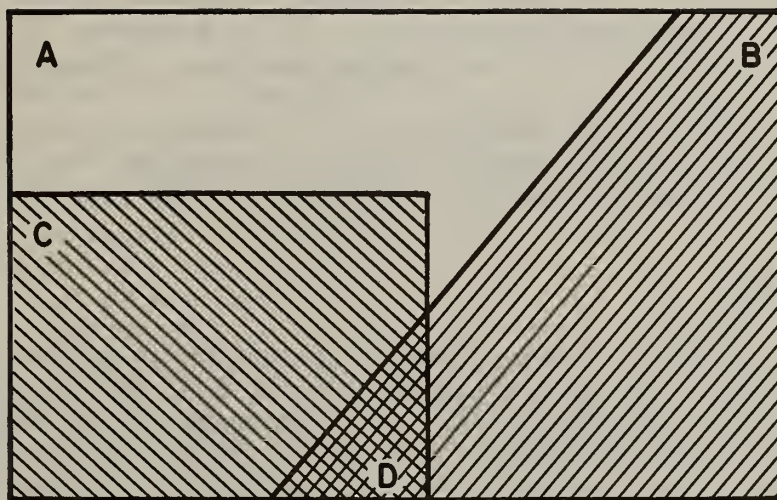


Figure III.E.6 Multiple shadow overlaps

III.F INTERNAL HEAT GAINS

III.F.1 SOURCES AND TYPES OF GAINS

Internal heat gains from lights, people, and equipment of various types are usually significant elements in the zone thermal balance. TARP allows the user to specify heat gains from equipment of various types, lights, occupants, and baseboard heat controlled by outdoor temperature. The total heat gain is made up of convective, radiant, and latent gains in various proportions from each of these sources. Convective gains are instantaneous additions of heat to the zone air. Radiant gains are distributed on the surfaces of the zone, where they are first absorbed and then released back into the room (and some fraction conducted through the surface) according to the surface heat balances (section I). Latent gains must be handled by ventilation or air conditioning equipment. Recommended heat gains for many items of equipment are given by ASHRAE [1]. These recommendations include the sensible (convective plus radiative) and latent proportions. Sensible gains from equipment are predominately radiant. The user can specify the heat gains and proportions appropriate for any type of equipment. The gains from lights, people, and baseboard heat are slightly more complicated.

III.F.1.1 LIGHTS

Radiant gains from lights must be handled differently from other radiant gains for reasons described in F.2. It is necessary to divide the total radiant gains into visible and thermal portions. The total electric input to typical incandescent lights is converted into 10 percent visible radiation, 80 percent thermal radiation and 10 percent convective gain. The electric input to typical fluorescent lights is converted into 20 percent visible radiation, 20 percent thermal radiation, and 60 percent convective gain [2].

III.F.1.2 PEOPLE

Heat is generated in the human body by oxidation at a rate called the metabolic rate. This heat is dissipated from the body surface and respiratory tract by a combination of radiation, convection, and evaporation. The relative portions of sensible (radiation plus convection) and latent (evaporation) heat from people is a complex function of the metabolic rate and environmental conditions. TARP uses a polynomial function to divide the total metabolic heat gain into sensible and latent portions. That function is based upon a fit to data [3] at average adjusted metabolic rates of 350, 400, 450, 500, 750, 850, 1000, and 1450 Btu/h each at temperatures of 70, 75, 78, 80, and 82 F. Sensible gains of 0 at 96 F and sensible gains equal to the metabolic rate at 30 F were assumed in order to give reasonable values beyond the reported temperature range. The original data for the polynomial was in English units, but the following correlation is in metric units.

$$\begin{aligned}
S = & 6.461927 + .946892*M + .0000255737*M^2 \\
& + 7.139322*T - .0627909*T*M + .0000589172*T*M^2 \\
& - .198550*T^2 + .000940018*T^2*M - .00000149532*T^2*M^2
\end{aligned} \tag{F.1.1}$$

where

M = metabolic rate (W)
T = air temperature (C)
S = sensible gain (W)
L = latent heat gain (W) [= M - S]

This function is compared to the original data points in figure F.1. The radiant fraction of the sensible gain is determined by the user.

III.F.1.3 BASEBOARD HEAT

Outdoor temperature controlled baseboard heat adds energy to the zone according a control profile as in figure F.2. At $T_a = T_2$, the baseboard heat gain is Q_2 . For $T_a > T_2$, there is no heat gain. For $T_a < T_1$, a maximum amount of energy, Q_1 , is added to the zone. There is proportional control between those temperatures:

$$Q = Q_2 - (Q_2 - Q_1)*(T_2 - T_a)/(T_2 - T_1) \tag{F.1.2}$$

III.F.2 DISTRIBUTION OF RADIANT GAINS

It is useful to consider the distribution of short wavelength (including visible) radiant energy separate from long wavelength (thermal) radiant energy because many materials have different optical properties at the different wavelengths. An extreme example is glass which is opaque to the long wavelengths and transparent to the short. Properties of materials vary across the entire spectrum of wavelengths. In TARP, all radiant interactions are represented in terms of only two wavelengths: "short" and "long". Short wavelength refers to the distribution given by a ~6000K black body source such as the sun. Long wavelengths refer to radiation from ~300K sources such as walls or people. there is negligible overlap between these two distributions. Some sources, such as lights, must be considered as emitting both long and short wavelength radiation in proportions which approximate their actual effects on room surfaces.

Long wavelength radiation from all internal sources, such as people, lights, and equipment, is combined and then uniformly distributed over all surfaces according to (H.2.5).

Some fraction of the beam solar radiation transmitted into the zone is directly absorbed by the interior surfaces according to the solar distribution algorithm (3.1.5) selected by the user. The beam radiation not directly absorbed, plus the diffuse sky and ground-reflected radiation, plus the short wavelength radiation from lights are combined and distributed over the surfaces of the zone according to:

$$QSI_1 = QS_n * \alpha_1 / \sum_{i=1}^{NS} S_i * (1 - \rho_i) \quad (F.2.1)$$

If all surfaces of the room are opaque, the radiation is distributed in proportion to the area*absorptance product of each surface. For surfaces which are transparent, $\rho_i = 1 - \alpha_i - \tau_i$. That fraction of radiation represented by τ_i is lost from the zone.

The transmittance and absorptance of transparent surfaces (windows) are calculated as in section D based on optical properties of the window material layers. The total absorptance of the window is computed for the interior shading device, the inside surface, and the outside surface for diffuse solar radiation incident from outside the zone. Those absorptances are used for short wavelength radiation incident from inside the zone. In most cases, this should not cause significant error. When movable insulation covers the window, the radiation which would have been transmitted is absorbed at the outer surface of the window (thermally equal to the inside surface of the insulation).

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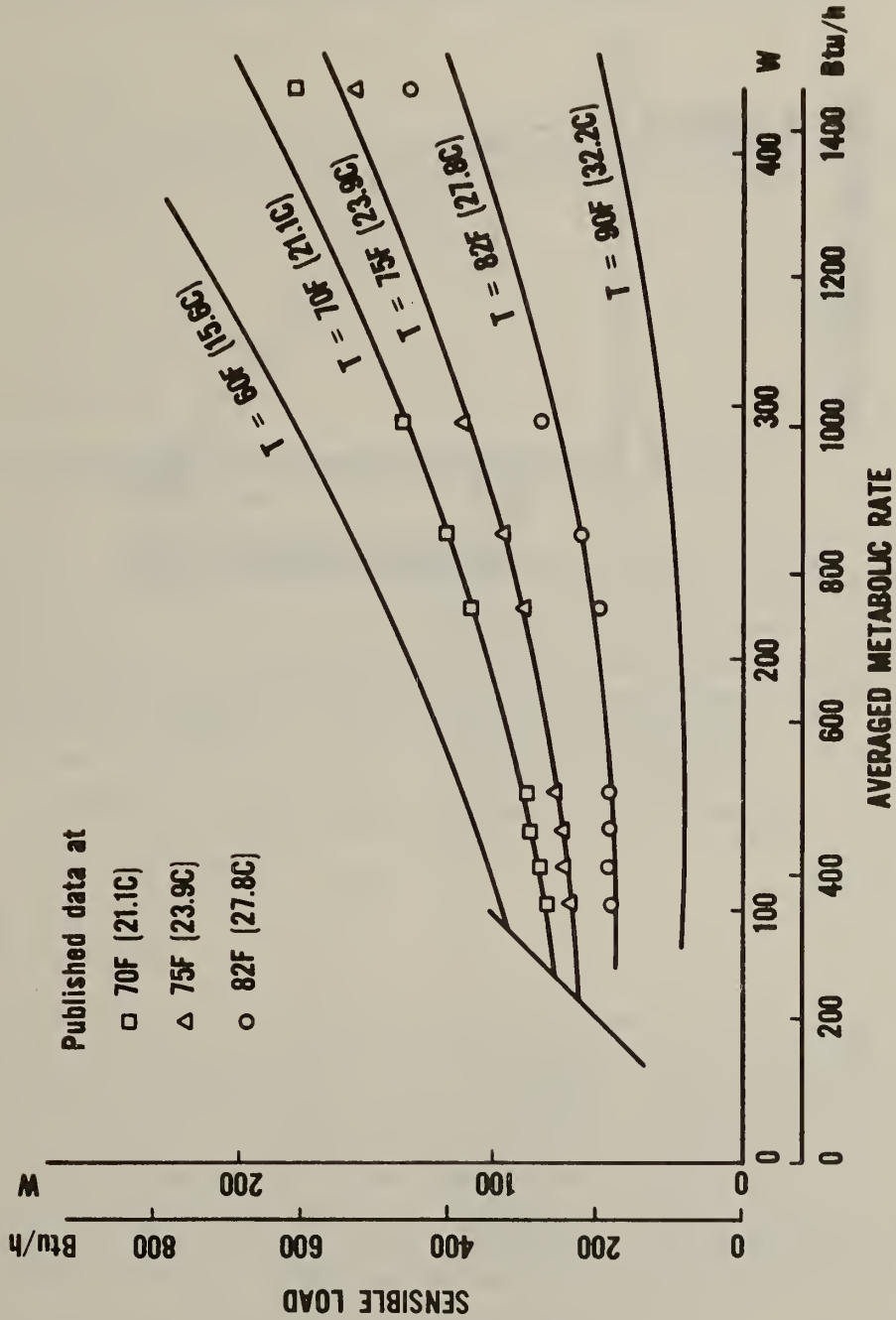


Figure III.F.1 Sensible heat gains from people

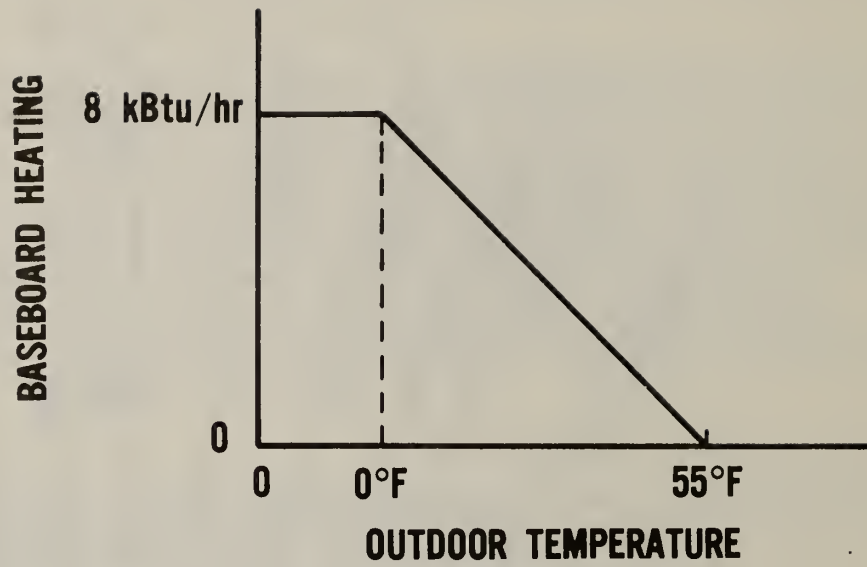


Figure III.F.2 Baseboard heat control profile

III.G NATURAL AIR MOVEMENTS

Most building surfaces contain openings, either large or small, which permit the movement of air through them whenever there is a pressure difference across the surface. Pressure differences arise from naturally occurring wind and thermal forces. The following discussion of air movements emphasizes the relationships to basic principles of fluid mechanics.

III.G.1 WIND FORCES

Wind pressures on surfaces are proportional to the velocity head of the undisturbed air stream [1]. The wind pressure is thus calculated from Bernoulli's equation as

$$PW_1' = 0.5 * D_a * V^2 \quad (G.1.1)$$

The density of air is given by

$$D_a = 0.0034838 * PB / T_a \quad (G.1.2)$$

The wind speed is evaluated at the highest point of the surface using the wind speed to height correlation (B.3.1).

Wind direction effects are dependent on the building's configuration and its relationship to surrounding structures. No single correlation can truly model directional effects on all buildings or even the effects on a single building in different environments. The following correlation is a compromise derived by averaging several published correlations [2, 3]. It accounts for the trends observed in wind pressure measurements.

Let Y = angle of incidence of wind on the surface ($0 \leq Y \leq 180$.)

$$\text{If } (Y \leq 90.) \quad PW_1 = (.75 - 1.05 * Y / 90.) * PW_1'$$

$$\text{If } (Y > 90.) \quad PW_1 = (0.15 * Y / 90. - .45) * PW_1' \quad (G.1.3)$$

III.G.2 THERMAL FORCES

Temperature differences cause air density differences which cause bouyancy (or "stack") effects. The magnitude of the force on a submerged surface (all surfaces are submerged in air) is equal to the area times the pressure at the centroid of the area. It is therefore necessary to know the pressure at the centroids and the locations of those centroids. The effect of air density on the pressure on any surface can be considered by a single simple formula. The pressure at height Z_1 is equal to the pressure at height Z_2 plus fluid density times the gravitational constant (9.80 m/s^2) times ($Z_2 - Z_1$). Figure G.1 shows a surface separating two vertically adjacent zones.

The pressure difference (ΔP) across the surface is $P_j - P_i$. It is more useful to know this ΔP in terms of zone pressures P_m and P_n :

$$P_j = P_m + D_m * g * (Z_m - Z_j) \quad (G.2.1a)$$

$$P_i = P_n + D_n * g * (Z_n - Z_i) \quad (G.2.1b)$$

The same formulae apply to a vertical surface as in figure G.2. They also apply to an envelope surface where P_j is the pressure of the outside air (figure G.3). Ambient air variables are substituted for the zone m variables:

$$P_j = P_a + D_a * g * (Z_a - Z_j) \quad (G.2.2)$$

Z_a is the reference height for air pressure measurements. Its location is arbitrary. The zone reference heights, Z_n and Z_m , are also arbitrary. All are chosen for convenient or physically meaningful representation.

The pressure difference across surface i is

$$\begin{aligned} \Delta P &= P_j - P_i \\ &= P_m - P_n + D_m * g * (Z_m - Z_j) - D_n * g * (Z_n - Z_i) \\ &= P_m - P_n + PS_i \end{aligned} \quad (G.2.3)$$

where

$$PS_i = D_m * g * (Z_m - Z_j) - D_n * g * (Z_n - Z_i)$$

is the "stack pressure" on surface i.

The height of the centroid of a triangle or rectangle is the average of the heights of the vertices. Since the stack effect also occurs within the thickness of a horizontal surface and since it is necessary to leave no building internal height unaccounted, Z_i and Z_j in figure G.1 should both be replaced by their average.

III.G.3 FLOW EQUATIONS

The flow through small openings in a surface is based on the orifice equation

$$F = C * A * D * \sqrt{2 * \Delta P / D} \quad (G.3.1)$$

where A is the observed opening area and where the flow coefficient, C, is a function of the Reynolds number and the ratio of the opening size to the entire surface. When the opening is small, C equals 0.6 for a wide range of Reynolds numbers [4]. TARP assumes this value of C. The user may modify C by using an effective flow area (FA) which differs from the actual proportional opening area. Experimental results indicate that flow through real surfaces is a combination of orifice flow ($F \propto \sqrt{\Delta P}$) and capillary flow ($F \propto \Delta P$) with an exponent of about 0.65 [5]. In order to retain the concept of opening area and provide a simple grouping of all other terms in (G.3.1), C is multiplied by $\sqrt{2}$ and D divided by \sqrt{D} to give:

$$F_i = 0.848 * FA_i * \sqrt{D} * (\Delta P)^{X_i} \quad (G.3.2)$$

where FA_i is the effective flow area of the openings in the surface, D is the density of incoming air, and X_i is the flow exponent. The pressure difference for envelope surfaces is

$$\Delta P = PW_i + PS_i - P_n \quad (G.3.3a)$$

and the ΔP for interzone surfaces is

$$\Delta P = PS_i + P_m - P_n \quad (G.3.3b)$$

The surface flow equation becomes

$$F_i = 0.848 * FA_i * /D_m * (\Delta P)^{X_i} \quad (\Delta P > 0) \quad (G.3.4a)$$

or

$$F_i = -.848 * FA_i * /D_n * (-\Delta P)^{X_i} \quad (\Delta P < 0) \quad (G.3.4b)$$

For each zone there must be a mass balance

$$F_s + \sum F_i = 0 \quad (G.3.5)$$

where F_s is the net mass flow into the zone from the air handling system and the F_i are the flows through openings in the zone envelope surfaces. These mass balances form a system of non-linear algebraic equations which can be solved for the zone pressures.

III.G.4 SOLUTION OF THE FLOW EQUATIONS

In some schemes for the evaluation of these simultaneous equations it is important to know the following partial derivatives:

$$\frac{\partial F_i}{\partial P_n} = -X_i * F_i / \Delta P \quad (G.4.1a)$$

$$\frac{\partial F_i}{\partial P_m} = X_i * F_i / \Delta P \quad (\text{interzone surface}) \quad (G.4.1b)$$

or

$$\frac{\partial F_i}{\partial P_m} = 0 \quad (\text{envelope surface}) \quad (G.4.1c)$$

Note that it is not necessary to evaluate $(\Delta P)^{(X_i-1)}$ to compute these derivatives. Note also that as ΔP approaches zero these derivatives cannot be evaluated. This condition applies for large openings which cannot support a large pressure difference (except with very high flow rates). This is a potential source of trouble which must be considered.

These equations have been successfully solved by a modified Newton's method in all cases tested. A standard Newton's method was found to sometimes give very slow convergence because of overcorrections during the iteration. The modification reduces the Newton correction when this problem appears to occur.

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- [5] ASHRAE Handbook - 1981 Fundamentals (ASHRAE, 1981), p 22.8.

$$F_i = 0.848 * FA_i * \sqrt{D} * (\Delta P)^{X_i} \quad (G.3.2)$$

where FA_i is the effective flow area of the openings in the surface, D is the density of incoming air, and X_i is the flow exponent. The pressure difference for envelope surfaces is

$$\Delta P = PW_i + PS_i - P_n \quad (G.3.3a)$$

and the ΔP for interzone surfaces is

$$\Delta P = PS_i + P_m - P_n \quad (G.3.3b)$$

The surface flow equation becomes

$$F_i = 0.848 * FA_i * /D_m * (\Delta P)^{X_i} \quad (\Delta P > 0) \quad (G.3.4a)$$

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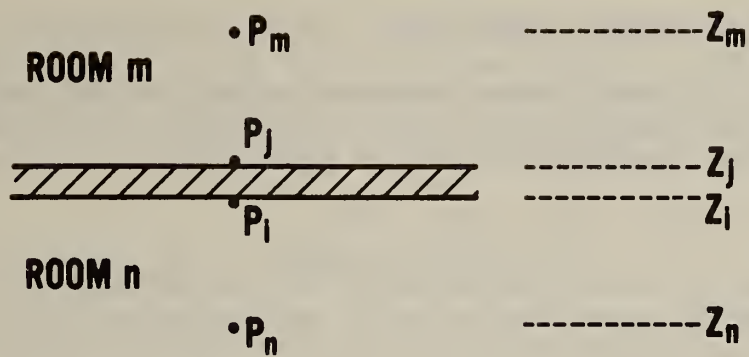


Figure III.G.1 Pressure relationships for vertically adjacent zones

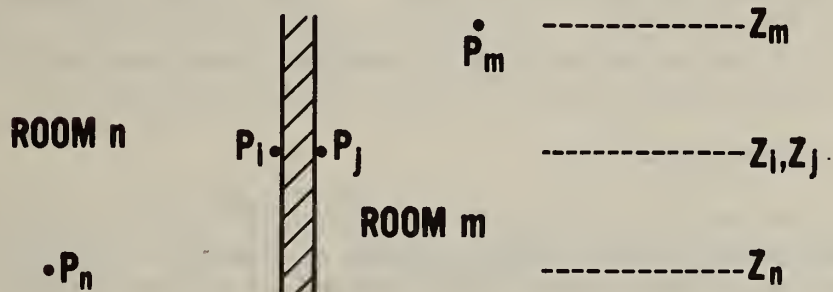


Figure III.G.2 Pressure relationships for horizontally adjacent zones

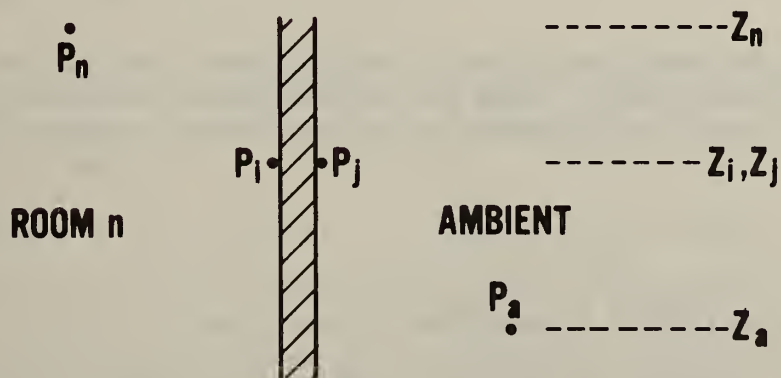


Figure III.G.3 Pressure relationships for envelope surfaces

III.H ROOM RADIANT INTERCHANGE

III.H.1 DETAILED RADIANT INTERCHANGE

The surfaces of a room form an enclosure where they exchange energy with the room air by convection and directly with each other by radiation. The net radiant flux absorbed by surface i is given by

$$QI_i = \sum_j F_{ij} * (\underline{T}_j^4 - \underline{T}_i^4) + QLI_i + QSI_i \quad (H.1.1)$$

This expression is not usually substituted into the surface heat balance equations since the \underline{T}^4 terms would make the equations nonlinear and difficult to solve. The radiation interchange factor, F_{ij} (which includes geometry and radiosity factors) is difficult to calculate for rooms with arbitrary geometry. Since each surface interacts with all other surfaces of the room (total of N surfaces) there are N^2 interactions to be considered. This requires a time consuming solution technique. Quicker solutions are possible by linearizing and assuming constant radiative and convective coefficients for all surfaces [1]. Alternate methods are available which use mean radiant temperature instead of the detailed radiant interchange. These methods allow efficient treatment of the problem without assuming constant coefficients. They so significantly affect the solution time for problems with many surfaces that they make simultaneous heat balances for many rooms feasible [2].

III.H.2 MRT NETWORK ALGORITHM

In the TARP radiant interchange between room surfaces is based on the mean radiant temperature network (MRTN) method of Joseph A. Carroll [3]. Surfaces radiatively interact with an MRT instead of directly with each other.

$$QI_i = HR_i * (TR_n - T_i) \quad (H.2.1)$$

where HR_i is a radiative conductance. This gives N instead of N^2 interactions. The time required to solve the inside surface heat balances is reduced from order N^2 to order N . The effects of QLI_i and QSI_i are discussed below.

Since the MRT includes the effect of all surfaces, coupling the surface to the MRT couples it to itself. The MRT network method includes a factor F_i , the "MRT view factor", which compensates for the self weight of surface i in the MRT.

$$F_i = 1 / [1 - S_i * F_i / (\sum_j S_j * F_j)] \quad (H.2.2)$$

This expression can be solved iteratively.

The effects of surface emittance are modeled by a surface resistance in the radiative conductance.

$$HR_i = 4\sigma T^3 / [1/F_i + (1-\epsilon_i)/\epsilon_i] \quad (H.2.3)$$

Near room temperature the radiative couplings between surfaces vary by about 1 percent per degree C variation in the mean radiant temperature. The TARP allows a quick mode of calculating the radiant interchange which uses a constant T (= 296K = 23C) for evaluating HR_i . A more accurate model uses the following algorithm to account for the non-linearity of the detailed equation.

1. Initialize all the HR_i for a temperature of 27C:

$$HR_i = 6.13 / [1/F_i + (1-\epsilon_i)/\epsilon_i] \quad (H.2.4a)$$

2. At each iteration first adjust all

$$HR_i = (0.865 + 0.005T_i) * HR_i \quad (H.2.4b)$$

3. Then evaluate

$$TRL_n = \sum HR_i A_i T_i / \sum HR_i A_i \quad (H.2.4c)$$

where the sum applies to all surfaces of room n

4. Then again adjust all

$$HR_i = (0.865 + 0.005TRL_n) * HR_i \quad (H.2.4d)$$

This method scales each HR_i by two factors nearly proportional to $T^{1.5}$, and estimates the radiant fluxes to within about 1 percent for surfaces between 0C and 50C.

In addition to the radiation from other surfaces, there is longwave radiation from various energy sources in the room. The effect of these radiant sources can be factored into the MRT and the radiant flux automatically distributed over the room surfaces.

$$TR_n = (\sum HR_i S_i T_i + QL_n) / \sum HR_i S_i \quad (H.2.5)$$

Shortwave radiation, such as from the sun and lights, should not be handled by this modification of the MRT because the room surfaces can have entirely different emissivities for short and long wavelength radiation. Therefore, H.2.1 should be written:

$$QI_i = HR_i (TR_n - T_i) + QSI_i \quad (H.2.6)$$

The MRTN method of Carroll is slightly more accurate than the "balanced mean radiant temperature" (MRTB) method of Walton. In addition it can easily handle multiple reflections and air emittance effects. However, when MRTN is used in the TARP iterative heat balance, it is slower than MRTB. A single MRTN iteration is slightly faster than MRTB, but more are required. This is because MRTN updates TR_n once per heat balance iteration of all

surfaces while MRTB updates TR_n for each surface during the heat balance iteration. The effect is the same as Jacobi versus Gauss-Seidel iteration [4]. The MRTN method was chosen over MRTB because of its accuracy and potential for future expansion. It thus became important to find a method to reduce the number of iterations to regain speed similar to MRTB. This method is described in section L.

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III.I SURFACE OUTSIDE HEAT BALANCES

III.I.1 SIMPLE SURFACE CONDUCTANCE

The convective plus radiative heat flux from a surface to the environment may be represented by:

$$CO + QO = HO * (TO - T_a) + QSO \quad (I.1.1)$$

The surface coefficient, HO , accounts for both convection and longwave radiant interchange. QSO is the absorbed shortwave radiant flux. A simple correlation for HO uses a polynomial expression [1] based on an ASHRAE relationship [2] which relates the surface coefficient (W/m^2K) to wind speed (m/s) and surface roughness.

$$H_0 = A_0 + A_1 * V_a + A_2 * V_a^2 \quad (I.1.2)$$

The values of the coefficients are determined by the surface roughness:

Roughness Index	A_0	A_1	A_2	Example Material
1	11.58	5.894	0.0	Stucco
2	12.49	4.065	0.028	Brick, rough plaster
3	10.79	4.192	0.0	Concrete
4	8.23	4.00	-0.057	Clear pine
5	10.22	3.10	0.0	Smooth plaster
6	8.23	3.33	-0.036	Glass, paint on pine

V_a is the reported wind speed unmodified for surface height or orientation. This is reasonable for estimating design loads, but it needs improvement for detailed simulations.

Rain causes the surface temperature to rapidly approach the water temperature. TARP models this by setting HO to $1000. W/m^2K$ and replacing T_a in (I.1.1) by the wet bulb temperature.

III.I.2 DETAILED SURFACE CONDUCTANCE

A detailed description of the outside surface coefficient must include components of forced convection (H_f), natural convection (H_n), and radiant interchange (H_r). These are affected by surface size, shape, location, orientation, and many features in the surrounding environment. All of these effects are open to further study [3]. The following algorithms have been combined (perhaps not justifiably) to allow the user to study the effects of certain details in the outside conductance algorithm on relative zone conditions. They show the kind of details that can be considered in TARP. They will be progressively enhanced as better algorithms are developed.

III.I.2.1 FORCED CONVECTION

Wind velocity tends to increase at increasing heights above the ground. The relationship for this increase is described in B.3.

$$V_{az} = V_a * b * (Z/Z_o)^a \quad (I.2.1)$$

Studies of the effect of surface shape on H_f give the following correlation [4].

$$St * Pr^{2/3} = 0.86 * Re^{-1/2} \quad (I.2.2)$$

or

$$H_f = 0.86 * D_a * C_p * P_r^{-2/3} * (.25 * V_{az} * C_v / A)^{1/2} \quad (I.2.3)$$

where

St = Stanton number ($H_f / D_a C_p V_z$)
 Pr = Prandtl number ($C_p v / k$)
 Re = Reynolds number ($4 V_{az} A / C v$)
 A = surface area
 C = surface circumference
 D_a = density of air
 C_p = specific heat of air
 V_{az} = free stream wind velocity (at height of surface)
 v = kinematic viscosity

For air $Pr^{-2/3} = 1.245$, $C_p = 1004 \text{ J/Kg K}$, and $D_a \sqrt{v} \cong 0.00472 \text{ Kg/s m}^{5/2}$ which combine to give

$$H_f = 2.537 * \sqrt{C/A} * \sqrt{V_{az}} \quad (I.2.4)$$

The local value of H_f was found to be greatest near the edges of the surface where the thermal boundary layer is thinnest. Therefore, to avoid computing too large a value for small subsurfaces (windows and doors), TARP uses the same C/A for the subsurfaces as for the wall they are on.

There is as yet no definitive study giving an algorithm for wind direction effects. Therefore, it was decided to follow the suggestion of Cole [5] and multiply H_f by a wind direction modifier, W_f , of one half for the leeward surfaces. W_f equals one for windward surfaces. In TARP leeward is defined as greater than 100 degrees from normal incidence.

A simple surface roughness multiplier, R_f , was developed from the ASHRAE graph of surface conductances [6]. At 0 mph all lines on this graph intercept at about $1.9 \text{ Btu/hrft}^2\text{F}$. The correlations for the six roughnesses are nearly linear. Therefore, a simple roughness multiplier was constructed by subtracting 1.9 from all values of H (at 25 mph) and dividing by the quantity $[H \text{ (of roughness 6 at 25 mph)} - 1.9]$ as summarized below.

Roughness	H (at 25 mph)	R _f
1	13.6	2.1
2	10.8	1.67
3	10.1	1.52
4	8.0	1.13
5	7.9	1.11
6	7.3	1.00

III.1.2.2 NATURAL CONVECTION

There must be a natural convection component in the overall surface coefficient to account for the convection which exists at zero wind velocity. The same expressions are used for outside natural convection as for inside convection (J.2).

$$\text{Heat flow up: } H_n = 9.482 \cdot 3 \sqrt{|T_o - T_a| / (7.238 - |\cos \phi|)} \quad (\text{I.2.5a})$$

$$\text{Heat flow down: } H_n = 1.810 \cdot 3 \sqrt{|T_o - T_a| / (1.381 + |\cos \phi|)} \quad (\text{I.2.5b})$$

This component is assumed to be present at all wind speeds.

III.1.2.3 RADIANT INTERCHANGE

There is radiant interchange between the surface and the sky, and between the surface and the ground surface or adjacent structures. The effective temperature of the ground surface is assumed to be equal to T_a (pending further algorithm development). The effective temperature of any point in the sky depends on the optical path length through the atmosphere. Section B.3 describes the algorithm which computes the effective sky temperature which would be seen by a horizontal surface. For tilted surfaces the radiant interchange coefficient (H_r) must be divided into three parts: one (HS) to sky temperature, one (HG) to ground surface temperature, and one (Ha) to air temperature.

$$H_a = \sigma * \epsilon * F_{ss} * (1 - \cos(\phi/2)) * (T_o^4 - T_a^4) / |T_o - T_a| \quad (\text{I.2.6a})$$

$$H_s = \sigma * \epsilon * F_{ss} * \cos(\phi/2) * (T_o^4 - T_s^4) / |T_o - T_s| \quad (\text{I.2.6b})$$

$$H_g = \sigma * \epsilon * F_{sg} * (T_o^4 - T_g^4) / |T_o - T_g| \quad (\text{I.2.6c})$$

Pending further research, TARP assumes the ground surface temperature, T_g , equals the air temperature, T_a . This three component split of H_r must still be validated or modified by experimental data. It produces proper results for horizontal surfaces. It causes a vertical surface to radiate to an effective temperature of $(.35 T_s + .65 T_a)$. TARP allows for radiant exchange to surfaces of buildings to be represented by the user-specified values of F_{ss} and F_{sg} . Other building surfaces can be expected to have about the same temperature as the surface in question. Therefore, there is no net radiant transfer to it, and the view factor to all other building surfaces is represented by $1 - F_{ss} - F_{sg}$.

III.1.2.4 COMBINED FACTORS

Since the expressions for H_n and H_r are used to evaluate T_0 , the most recent value of T_0 is used in their calculation. The three factors combine to give the following expression for combined convective and radiative flux.

$$C_0 + Q_0 = (H_f * W_f * R_f + H_n + H_A) * (T_a - T_0) + H_S * (T_s - T_0) + H_G * (T_g - T_0) + Q_{SO} \quad (I.2.7)$$

III.1.3 BASIC HEAT BALANCES

A heat balance must exist at the outside surface-air interface. The incoming conductive, convective, and radiative fluxes must sum to zero:

$$K_0 + C_0 + Q_0 = 0 \quad (I.3.1)$$

In contrast to the internal surface heat balance which treats all surfaces simultaneously, the external thermal balance for each surface is performed independent of all other surfaces. This implies that there is no direct interaction between the individual surfaces.

The TARP includes four possible representations for the basic outside surface heat balance. The first two depend on which of the optional surface conductance algorithms the user selects. The simple outside surface conductance (I.1) which includes both the convective and thermal interchange between the surface and the environment in a single coefficient, is represented by the thermal network in figure I.1. (I.3.1) can be expressed in terms of (C.1.6) and (I.1.1) as

$$KOP_t + Y_0 * TI_t - X_0 * TO_t + HO * (T_a - TO_t) + Q_{SO} = 0 \quad (I.3.2)$$

This can be solved for the outside surface temperature.

$$TO_t = (KOP_t + Q_{SO} + Y_0 * TI_t + HO * T_a) / (X_0 + HO) \quad (I.3.3)$$

The detailed outside surface conductance model (I.2) considers convection and radiant interchange with the sky and with the ground as separate factors. Its use in the outside thermal balance is shown in figure I.2. In this case (I.3.1) can be expanded according to (C.1.6) and (I.2.7) to give

$$\begin{aligned} KOP_t + Y_0 * TI_t - X_0 * TO_t + H_A * (T_a - TO_t) \\ + H_S * (T_s - TO_t) + H_G * (T_g - TO_t) + Q_{SO} = 0 \end{aligned} \quad (I.3.4)$$

This can be solved for the outside surface temperature:

$$\begin{aligned} TO_t = (KOP_t + Q_{SO} + Y_0 * TI_t + H_A * T_a + H_S * T_s + H_G * T_g) \\ / (X_0 + H_A + H_S + H_G) \end{aligned} \quad (I.3.5)$$

The third and fourth representations occur when the outside surface has been covered with a movable insulation. The insulation has a conductance of UM. This case is represented by the thermal network in figure I.3. The insulation must be massless because it is not generally possible to perform a correct thermal balance at the juncture of two surfaces each modeled by CTF.

The equation for the thermal balance between the surface and the insulation is

$$KOP_t + Y_0 * TI_t - X_0 * TO_t + UM * (TM - TO_t) + QSO = 0 \quad (I.3.6)$$

which can be rewritten to solve for TO:

$$TO_t = (KOP_t + QSO + Y_0 * TI_t + UM * TM) / (X_0 + UM) \quad (I.3.7)$$

Depending on whether or not the detailed or simple algorithm for surface conductance is being used, there are two expressions for TM, the outside temperature of the insulation. For the simple conductance:

$$TM = (QSM + UM * TO_t + HO * T_a) / (UM + HO) \quad (I.3.8)$$

For the detailed conductance:

$$TM = (QSM + UM * TO_t + HA * T_a + HS * T_s + HG * T_g) / (UM + HA + HS + HG) \quad (I.3.9)$$

In this case the values of HA, HS, and HG must be found by using an estimated value of TM in place of TO in (I.2).

III.I.4 HEAT BALANCE CASES

TO_t and TI_t are related through the Y_0 CTF. However, TI_t is also unknown. While it is possible to combine the outside and inside surface heat balances to compute TO_t and TI_t simultaneously, the TARP uses a simpler procedure where TO_t is based on a previous value of TI . When Y_0 is small, as occurs in well insulated or very massive surfaces, TI_t can be replaced by TI_{t-1} (which is known from the previous hour's heat balance) without significantly effecting the value of TO_t . When Y_0 is large, TO and TI can be so strongly coupled that separate outside and inside heat balances do not work because the environment and zone temperatures have negligible influence on the heat balances. The TARP uses the inside surface heat balance to couple TO_t with TZ and TR . These two temperatures are less strongly influenced by TO and allow a reasonable heat balance. On the first heat balance iteration, TZ and TR are the values at time $t-1$. The user may optionally require that TO_t be recomputed with every iteration of TI_t . In this case TZ and TR have the values from the previous iteration, and a true simultaneous solution is achieved. In most conventional construction, recomputing TO_t does not significantly change the computed zone loads and temperatures. The inside surface heat balance is given by (J.3.3) which is repeated here.

$$TI_t = (KIP_t + QSI + HC * TZ + HR * TR + Y_0 * TO) / (Z_0 + HC + HR) \quad (I.4.1)$$

The surface heat balances can be combined in eight ways according to conditions for calculation of the outside surface temperature. Compute

$$F_1 = Y_0 / (Z_0 + HI + HR) \quad (I.4.2a)$$

$$F_2 = UM / (UM + HO) \quad (I.4.2b)$$

$$F_3 = UM / (UM + HA + HS + HG) \quad (I.4.2c)$$

as needed for the following cases.

CASE 1: Y_0 small, simple conductance, no movable insulation. From equation (I.3.3):

$$TO_t = (KOP_t + QSO + Y_0 * TI_{t-1} + HO * T_a) / (X_0 + HO) \quad (I.4.3)$$

CASE 2: Y_0 not small, simple conductance, no movable insulation. From (I.3.3) and (I.4.1):

$$TO_t = [KOP_t + QSO + HO * T_a + F_1 * (KIP_t + QSI + HI * TZ + HR * TR)] / (X_0 + HO - F_1 * Y_0) \quad (I.4.4)$$

CASE 3: Y_0 small, detailed conductance, no movable insulation. From (I.3.4):

$$TO_t = (KOP_t + QSO + Y_0 * TI_{t-1} + HA * T_a + HS * T_s + HG * T_g) / (X_0 + HA + HS + HG) \quad (I.4.5)$$

CASE 4: Y_0 not small, detailed conductance, no movable insulation. From (I.3.4) and (I.4.1):

$$TO_t = [KOP_t + QSO + HA * T_a + HS * T_s + HG * T_g + F_1 * (KIP_t + QSI + HI * TZ + HR * TR)] / (X_0 + HA + HS + HG - F_1 * Y_0) \quad (I.4.6)$$

CASE 5: Y_0 small, simple conductance, with movable insulation. From (I.3.7) and (I.3.8):

$$TO_t = [KOP_t + QSO + Y_0 * TI_{t-1} + F_2 * (QSM + HO * TM)] / (X_0 + UM - F_2 * UM) \quad (I.4.7)$$

CASE 6: Y_0 not small, simple conductance, with movable insulation. From (I.3.7), (I.3.8), and (I.4.1):

$$TO_t = [KOP_t + QSO + F_2 * (QSM + HO * T_a) + F_1 * (KIP_t + QSI + HI * TZ + HR * TR)] / (X_0 + UM - F_2 * UM - F_1 * Y_0) \quad (I.4.8)$$

CASE 7: Y_0 small, detailed conductance, with movable insulation. From (I.3.7) and (I.3.9):

$$TO_t = [KOP_t + QSO + Y_0 * TI_{t-1} + F_3 * (QSM + HA * T_a + HS * T_s + HG * T_g)] / (X_0 + UM - F_3 * UM) \quad (I.4.9)$$

CASE 8: Y_0 not small, detailed conductance, with movable insulation. From (I.3.7), (I.3.9), and (I.4.1):

$$TO_t = [KOP_t + QSO + F_1 * (KIP_t + QSI + HI * TZ + HR * TR) + F_3 * (QSM + HA * T_a + HS * T_s + HG * T_g)] / (X_0 + UM - F_3 * UM - F_1 * Y_0) \quad (I.4.10)$$

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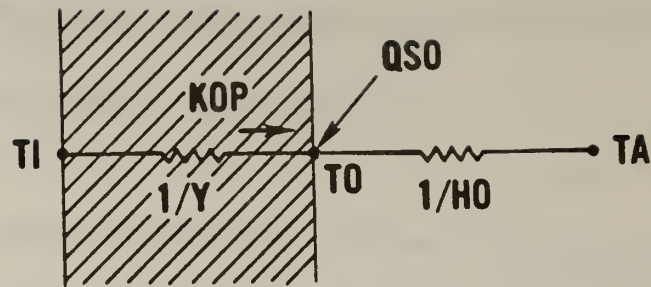


Figure III.I.1 Thermal network for simple outside surface coefficient

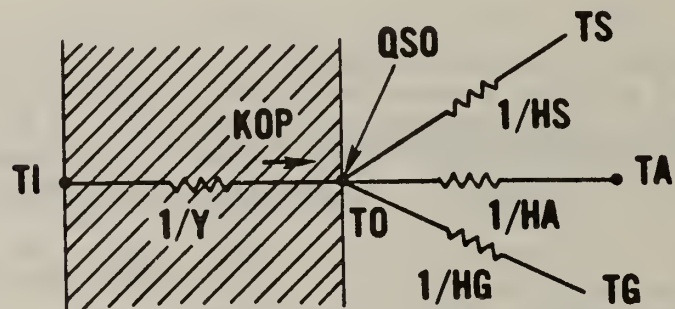


Figure III.I.2 Thermal network for detailed outside surface coefficient

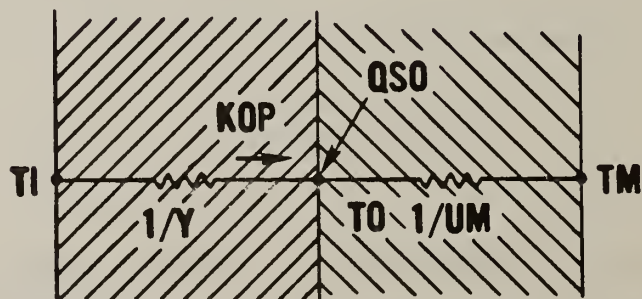


Figure III.I.3 Thermal network for outside movable insulation

III.J SURFACE INSIDE HEAT BALANCES

III.J.1 SIMPLE CONVECTION COEFFICIENT

The convective heat flux from the zone air to a surface is given by:

$$CI = HC * (TI - TZ) \quad (J.1.1)$$

The coefficient for natural convection heat transfer is based on data from ASHRAE [1]. The ASHRAE values are for combined convection and radiation, so a radiative component of (1.02 times emissivity of 0.9) is subtracted from the tabulated values which are then converted to metric. When warm air is below a cool horizontal surface (or cool air above a warm surface), there is more convective mixing than for air next to a vertical surface. Conversely, when cool air is below a warm surface (or warm air above a cool surface) there is reduced convection.

HC (W/m ² K)	Type of Heat Flow	Surface Tilt
4.043	enhanced	157.5 to 180 or 0 to 22.5 degrees
3.873	enhanced	112.5 to 157.5 or 22.5 to 67.5 degrees
3.078	normal	67.5 to 112.5 degrees (vertical surface)
2.283	reduced	22.5 to 67.5 or 112.5 to 157.5 degrees
0.920	reduced	0 to 22.5 or 157.5 to 180 degrees

When the air handling system is moving air through the zone, a single value of 6.14 W/m²K (= 2.0 - 1.02 * 0.90 Btu/h*ft²*F) should be used for HI.

III.J.2 DETAILED NATURAL CONVECTION COEFFICIENT

ASHRAE has the following expressions for natural convection from large surfaces [2].

HC (W/m ² K)	Direction of Heat Flow	
$1.52 * \sqrt[3]{ TZ-TI }$	Upward	(J.2.1a)
$1.31 * \sqrt[3]{ TZ-TI }$	Horizontal	(J.2.1b)
$0.76 * \sqrt[3]{ TZ-TI }$	Downward	(J.2.1c)

It may be noted that these expressions are inconsistent with the values given for the simple algorithm.

To account for all surface tilts, the following expressions are used.

Heat flow horizontal or upward:

$$HC = 9.482 * \sqrt[3]{|TZ-TI|} / (7.238 - |\cos\phi|) \quad (J.2.2a)$$

Heat flow horizontal or downward:

$$HC = 1.810 * \sqrt[3]{|TZ-TI|} / (1.382 + |\cos \phi|) \quad (J.2.2b)$$

III.J.3 BASIC HEAT BALANCE

A heat balance must exist at the inside surface-air interface. The incoming convective, radiative, and conductive fluxes must sum to zero:

$$CI_1 + QI_1 + KI_1 = 0.0 \quad (J.3.1)$$

This equation can be expanded according to the descriptions of convection (J.1 and J.2), radiation (F.2.6), and conduction (C.1.4) and as shown in figure J.1 to give

$$HC_1*(TZ_n-TI_1) + HR_1*(TR_n-TI_1) + QSI_1 + KIP_1 + Y_{0,1}*TO_1 - Z_{0,1}*TI_1 = 0.0 \quad (J.3.2)$$

Interior surface temperatures of envelope surfaces are computed by rearranging (J.3.2):

$$TI_1 = (HC_1*TZ_n + HR_1*TR_n + QSI_1 + KIP_1 + Y_{0,1}*TO_1) / (HC_1 + HR_1 + Z_{0,1}) \quad (J.3.3)$$

The value of TO_1 must have been previously calculated by the methods in section I.4.

The following two partial derivatives are useful in improving the rate of convergence of the heat balance iterations.

$$\frac{\partial TI_1}{\partial TZ_n} = HC_1 / (HC_1 + HR_1 + Z_{0,1}) \quad (J.3.4a)$$

$$\frac{\partial TI_1}{\partial TR_n} = HR_1 / (HC_1 + HR_1 + Z_{0,1}) \quad (J.3.4b)$$

III.J.4 INTERNAL SURFACES

Internal masses and partitions separating identically conditioned zones can be treated as surfaces with equal inside and outside temperatures. In that case Equation (J.3.2) may be rearranged to give:

$$TI_1 = (HC_1*TZ_n + HR_1*TR_n + QSI_1 + KIP_1) / (HC_1 + HR_1 + Z_{0,i} - Y_{0,i}) \quad (J.4.1)$$

The partial derivatives are

$$\frac{\partial TI_1}{\partial TZ_n} = HC_1 / (HC_1 + HR_1 + Z_{0,i} - Y_{0,i}) \quad (J.4.2a)$$

and

$$\frac{\partial TI_1}{\partial TR_n} = HR_1 / (HC_1 + HR_1 + Z_{0,1} - Y_{0,1}) \quad (J.4.2b)$$

III.J.5 INTERZONE SURFACES

In the TARP interzone surfaces are permitted to have movable insulation. This creates another set of basic heat balances at the air-insulation and the insulation-surface interfaces (figure J.2). The inside heat balances (with movable insulation) are

$$HC_1*(TZ_n - TM_1) + HR_1*(TR_n - TM_1) + UM_1*(TI_1 - TM_1) + QSM_1 = 0.0 \quad (J.5.1)$$

$$KIP_1 + Y_{0,1}*TO_1 - Z_{0,1}*TI_1 + UM_1*(TM_1 - TI_1) + QSI_1 = 0.0 \quad (J.5.2)$$

A similar set of equations exist for the far side of the surface (described as surface j adjacent to zone m). The far side heat balance (without movable insulation) is

$$HC_j*(TZ_m - TI_j) + HR_j*(TR_m - TI_j) + QSI_j + KIP_j + Y_{0,j}*TO_j - Z_{0,j}*TI_j = 0.0 \quad (J.5.3)$$

The far side heat balances (with movable insulation) are

$$HC_j*(TZ_m - TM_j) + HR_j*(TR_m - TM_j) + UM_j*(TI_j - TM_j) + QSM_j = 0.0 \quad (J.5.4)$$

$$KIP_j + Y_{0,j}*TO_j - Z_{0,j}*TI_j + UM_j*(TM_j - TI_j) + QSI_j = 0.0 \quad (J.5.5)$$

The following relationships apply because i and j refer to opposite sides of the same surface:

$$TI_i = TO_j; \quad TO_i = TI_j; \quad KIP_i = KOP_j; \quad KOP_i = KIP_j;$$

$$Z_{0,j} = X_{0,i} (= X_0); \quad Y_{0,j} = Y_{0,i} (= Y_0).$$

The placement of insulation on either side leads to four basic cases. Compute

$$F_1 = Y_0 / (X_0 + HC_j + HR_j) \quad (J.5.6a)$$

$$F_2 = UM_i / (UM_i + HC_i + HR_i) \quad (J.5.6b)$$

$$F_3 = UM_j / (UM_j + HC_j + HR_i) \quad (J.5.6c)$$

$$F_4 = Y_0 / (X_0 + UM_j - F_3*UM_j) \quad (J.5.6d)$$

as needed for the cases below.

CASE 1: No movable insulation on either side. From equations (J.3.2) and (J.5.3):

$$\begin{aligned}
TI_1 = & [HC_1*TZ_n + HR_1*TR_n + QSI_1 + KIP_1 + \\
& F_1*(HC_j*TZ_m + HR_j*TR_m + QSI_j + KIP_j)] \\
& / (Z_0 + HC_1 + HR_1 - F_1*Y_0)
\end{aligned} \tag{J.5.7}$$

The partial derivatives are:

$$\frac{\partial TI_1}{\partial TZ_n} = HC_1 / (HC_1 + HR_1 + Z_0 - F_1*Y_0) \tag{J.5.8a}$$

and

$$\frac{\partial TI_1}{\partial TR_n} = HR_1 / (HC_1 + HR_1 + Z_0 - F_1*Y_0) \tag{J.5.8b}$$

CASE 2: Movable insulation on near side only. From equations (J.5.1), (J.5.2), and (J.5.3):

$$\begin{aligned}
TI_1 = & [KIP_1 + QSI_1 + F_1*(HC_j*TZ_m + HR_j*TR_m + QSI_j + KIP_j) \\
& + F_2*(HC_1*TZ_n + HR_1*TR_n + QSM_1)] \\
& / (Z_0 + UM_1 - F_1*Y_0 - F_2*UM_1)
\end{aligned} \tag{J.5.9a}$$

$$TM_1 = F_2*[TI_1 + (HC_1*TZ_n + HR_1*TR_n + QSM_1)/UM_1] \tag{J.5.9b}$$

Since UM_1 should be small, the partial derivatives are:

$$\frac{\partial TI_1}{\partial TZ_n} = HC_1 / (HC_1 + HR_1 + UM_1) \tag{J.5.10a}$$

and

$$\frac{\partial TI_1}{\partial TR_n} = HR_1 / (HC_1 + HR_1 + UM_1) \tag{J.5.10b}$$

CASE 3: Movable insulation on far side only. From equations (J.3.2), (J.5.4), and (J.5.5):

$$\begin{aligned}
TI_1 = & \{HC_1*TZ_n + HR_1*TR_n + KIP_1 + QSI_1 \\
& + F_4*[KIP_j + QSI_j + F_3*(HC_j*TZ_m + HR_j*TR_m + QSM_j)]\} \\
& / (Z_0 + HC_1 + HR_1 - F_4*Y_0)
\end{aligned} \tag{J.5.11}$$

The partial derivatives are given by (J.5.8a) and (J.5.8b).

CASE 4: Movable insulation on both sides. QSI_1 and QSI_j are both zero because the insulation is assumed opaque. From equations (J.5.1), (J.5.2), (J.5.4) and (J.5.5):

$$\begin{aligned}
 TI_i = & \{ KIP_i + F_4*[KIP_j + F_3*(HC_j*TZ_m + HR_j*TR_m + QSM_j)] \\
 & + F_2*(HC_i*TZ_n + HR_i*TR_n + QSM_i) \} \\
 & / (Z_0 + UM_j - F_4*Y_0 - F_2*UM_i)
 \end{aligned}
 \tag{J.5.12a}$$

$$TM_i = F_2*[TI_i + (HC_i*TZ_n + HR_i*TR_n + QSM_i)/UM_i]
 \tag{J.5.12b}$$

The partial derivatives are given by (J.5.10a) and (J.5.10b).

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- [1] ASHRAE Handbook - 1981 Fundamentals (ASHRAE, 1981), p 23.12, Table 1.
- [2] ASHRAE Handbook - 1981 Fundamentals (ASHRAE, 1981), p 2.12, Table 5.

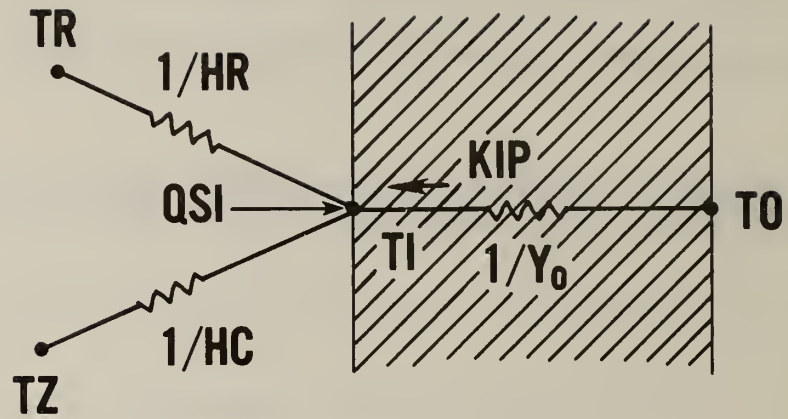


Figure III.J.1 Inside surface thermal network

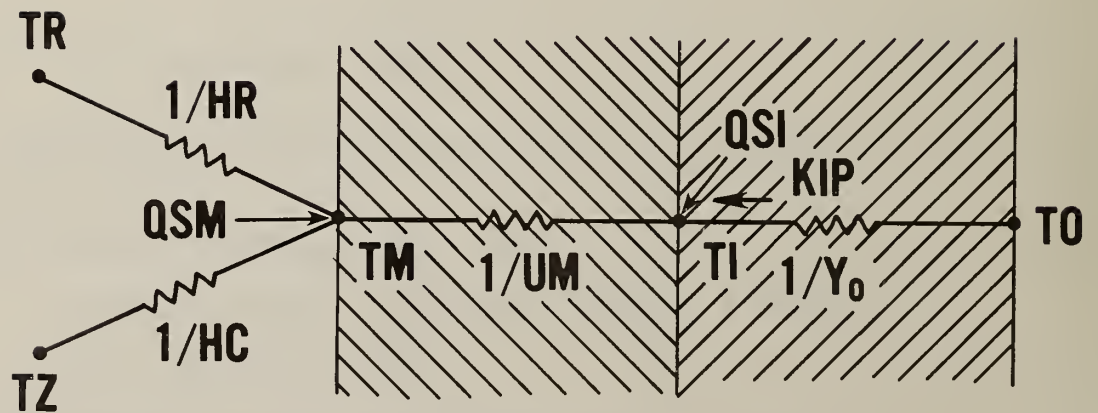


Figure III.J.2 Inside movable insulation thermal network

III.K ZONE AIR HEAT BALANCE

The calculation of the zone air temperature is based on a heat balance on the zone air. The convective gains from the room surfaces and internal sources plus the sensible gain from incoming air plus the energy added by the air handling system must equal zero.

$$CE + \sum HC_i * S_i * (T_i - T_Z) + \sum F_j * C_p * (T_{S_j} - T_Z) + L = 0 \quad (K.0.1)$$

The summations apply to all surfaces which are part of the zone.

The system performance model (III.K.1) may be used with the detailed natural air movement model (III.G) if the supply and exhaust air flows of every zone are equal (that is, F_s in equation (G.3.5) must be zero). The simple air movement models (III.K.2 through III.K.5) may not be used simultaneously with the detailed air movement model.

III.K.1 SYSTEM PERFORMANCE MODEL

The energy from the system is based on the user defined control profile which approximates the performance of the actual system. The control profile consists of a set of control points which define the heating or cooling capacity of the system as a function of the control temperature as in figure K.1. Control range p is between temperatures T_p and T_{p+1} . The control profile is linear between the control points. Simple proportionality gives

$$L = L_p + (T - T_p) * (L_{p+1} - L_p) / (T_{p+1} - T_p) \quad (K.1.1)$$

This can be rearranged to

$$L = LT * T + LC \quad (K.1.2a)$$

where

$$LT = (L_{p+1} - L_p) / (T_{p+1} - T_p) \text{ and } LC = L_p - LT * T_p \quad (K.1.2b)$$

The control temperature consists of both the air and the mean radiant temperatures according to the formula

$$T = \beta * T_R + (1 - \beta) * T_Z \quad (K.1.3)$$

where β is the user defined radiant fraction. When this expression is substituted into the zone air heat balance, it gives the following expression for computing the zone air temperature

$$T_Z = [CE + \sum HC_i * S_i * T_i + \sum F_j * C_p * T_{S_j} + \beta * LT * T_R + LC] / [\sum HC_i * S_i + \sum F_j * C_p - (1 - \beta) * LT] \quad (K.1.4)$$

III.K.2 SIMPLE INFILTRATION MODEL

An equation for the mass flow of infiltration air can be developed from measured values in similar structures [1]. The TARP assumes a correlation of the form

$$FI = (A_0 + A_1 * |TZ - T_a| + A_2 * V + A_3 * V^2) * D_a \quad (K.2.1)$$

This correlation accounts for stack effects in the temperature difference term and wind effects in the two velocity terms. Equation (K.1.4) simplifies to

$$TZ = [CE + \sum HC_1 * S_1 * T_1 + FI * C_p * T_a + \beta * LT * TR + LC] / [\sum HC_1 * S_1 + FI * C_p - (1 - \beta) * LT] \quad (K.2.2)$$

III.K.3 ZONE VENTILATION MODEL

The heating effect of ventilation air is given by

$$LV = FV * C_p * (T_a - TZ) \quad (K.3.1)$$

TARP ventilation operates by creation of a ventilation profile similar to the zone temperature control profile. A new ventilation profile is created every hour as the ambient temperature changes. No point on the ventilation profile is permitted to overlap the heating or cooling portions of the control profile. This assumes the same fan is used for ventilation and heating or at least that two separate fans are managed by the same controller.

Several types of ventilation profile are possible. Figure K.2 shows a profile when the ambient temperature (T_a) is higher than the desired temperature (TV). No cooling occurs until the zone air temperature exceeds T_a .

When T_a is less than TV , there is a cooling capacity at TV . A small ramp between TV and $TV+0.01$ is created for stability of the heat balance iterations as in figure K.3.

When there is a heating control profile and the desired ventilation temperature is below the point which initiates heating, the TARP revises TV to above that point as in figure K.4.

When there is a cooling control profile, the ventilation profile is not permitted to extend upward into the cooling temperature range (figure K.5).

III.K.4 TWO ZONE MIXING MODEL

A simple model can be developed to describe the forced mixing of air between two zones with simple controls. A mass flow of up to FM will exist from zone m to zone n when $TZ_m - TZ_n > TD$. It is assumed that an equal return flow exists from zone n to m . Since the two zone air temperatures

are intimately coupled, it is best to seek an exact simultaneous solution. The description of that solution is simplified by rearranging equation (K.2.2) to

$$B_n * TZ_n = A_n \quad (K.4.1)$$

where

$$A_n = CE_n + \sum HC_1 * TI_1 + FI_n * Cp_n * T_a + \beta * LT_n * TR_n + LC_n$$

$$B_n = \sum HC_1 + FI_n * Cp_n - (1 - \beta) * LT_n$$

A similar equation exists for zone m. The effect of an interzone air flow is given by the two equations

$$(B_n + MM) * TZ_n = A_n + MM * TZ_m \quad (K.4.2a)$$

$$(B_m + MM) * TZ_m = A_m + MM * TZ_n \quad (K.4.2b)$$

where $MM = FM * C_p$.

There are three possible conditions for the interzone air flow. First is that $TZ_m - TZ_n < TD$ and therefore $MM = 0$. Second is that the maximum flow rate still leaves $TZ_m - TZ_n > TD$. Simultaneous solution of equations (K.4.2a) and (K.4.2b) gives

$$TZ_n = (A_n + F_1 * A_m) / (B_n + MM - F_1 * MM) \quad (K.4.3a)$$

$$TZ_m = (A_m + MM * TZ_n) / (B_m + MM) \quad (K.4.3b)$$

where $F_1 = MM / (B_m + MM)$

The third case occurs when no flow gives $TZ_m - TZ_n > TD$ and full flow would cause $TZ_m - TZ_n < TD$. It is then necessary to solve for the partial flow during the hour which will cause $TZ_m - TZ_n = TD$. This gives

$$MM = [A_m - B_m * (TD + A_n / B_n)] / [TD * B_m / B_n + TD] \quad (K.4.4a)$$

$$TZ_n = (A_n + MM * TD) / B_n \quad (K.4.4b)$$

$$TZ_m = TZ_n + TD \quad (K.4.4c)$$

III.K.5 WHOLE HOUSE FAN MODEL

A model similar to the zone mixing model (III.K.4) can be developed which describes the effects of a fan moving air only from zone n to zone m with movement of air to and from ambient completing the mass balance. Such a case is the exhaust of house air into its attic. A simple control scheme allows a mass flow of up to FF whenever $TZ_n > TD > T_a$. The effect of the air flow on the zone energy balances is given by

$$(B_n + MF) * TZ_n = A_n + MF * T_a \quad (K.5.1a)$$

and

$$(B_m + MF) * TZ_m = A_m + MF * TZ_n \quad (K.5.1b)$$

where

$$MF = FF * C_p$$

similar to equations (K.4.2).

There are three possible conditions for the interzone air flow. First is that $TD < T_a$ or $TZ_n < TD$ which gives $MF=0$. Second is that the maximum flow leaves $TZ_n > TD$. Direct solution of equations 1a and 1b gives

$$TZ_n = (A_n + MF * T_a) / (B_n + MF) \quad (K.5.2a)$$

$$TZ_m = (A_m + MF * TZ_n) / (B_m + MF) \quad (K.5.2b)$$

The third case occurs when no flow gives $TZ_n > TD$ and full flow would cause $TZ_n < TD$. It is then necessary to solve for the partial flow during the hour which causes $TZ_n = TD$.

$$MF = (A_n - B_n * TD) / (TD - T_a) \quad (K.5.3a)$$

$$TZ_n = TD \quad (K.5.3b)$$

$$TZ_m = (A_m + MF * TZ_n) / (B_m + MF) \quad (K.5.3c)$$

REFERENCES

- [1] Coblenz, C. W. and Achenbach, P. R., "Field Measurements of Ten Electrically-Heated Houses", ASHRAE Transactions (ASHRAE, 1963), pp 358-365.

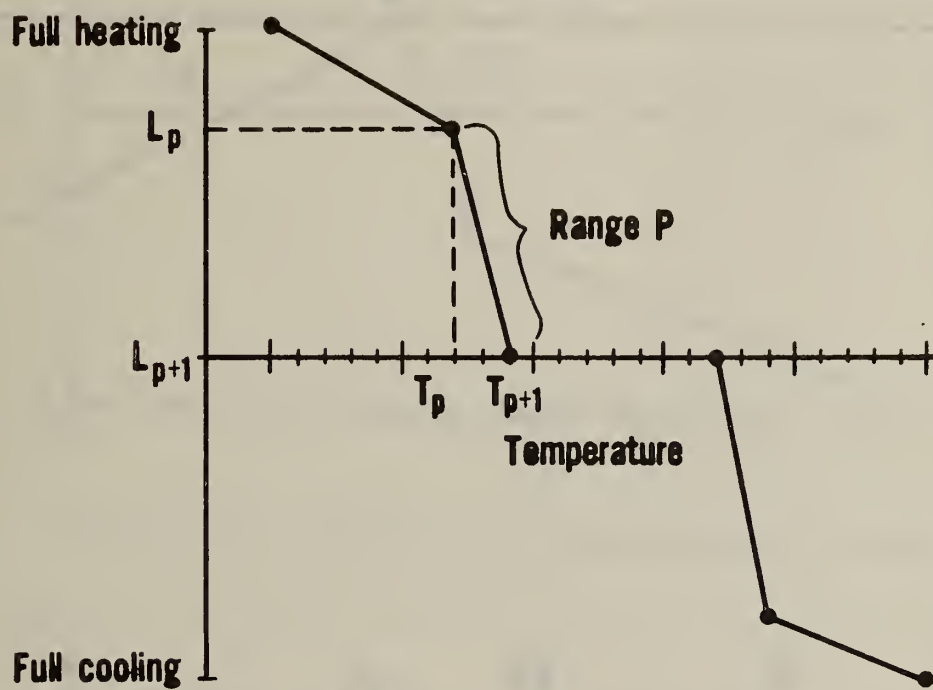


Figure III.K.1 Zone temperature control profile

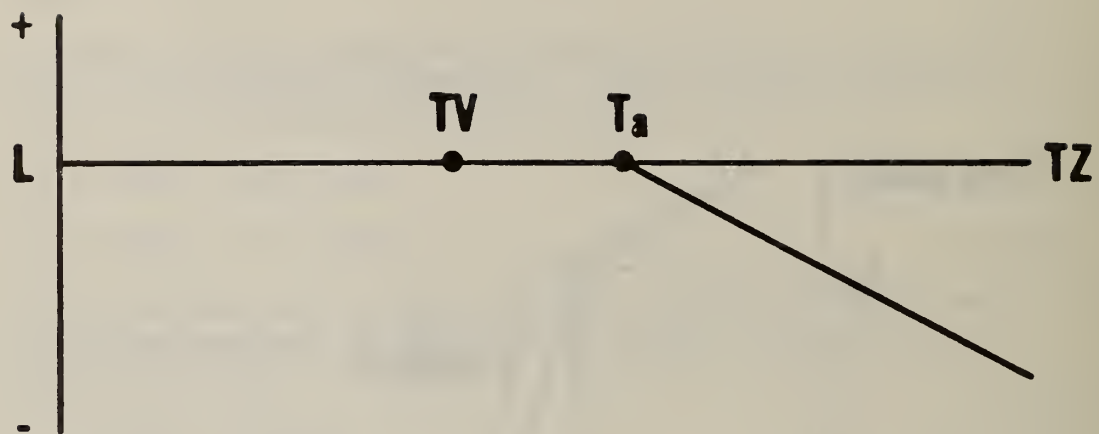


Figure III.K.2 Ventilation control profile: T_a higher than TV

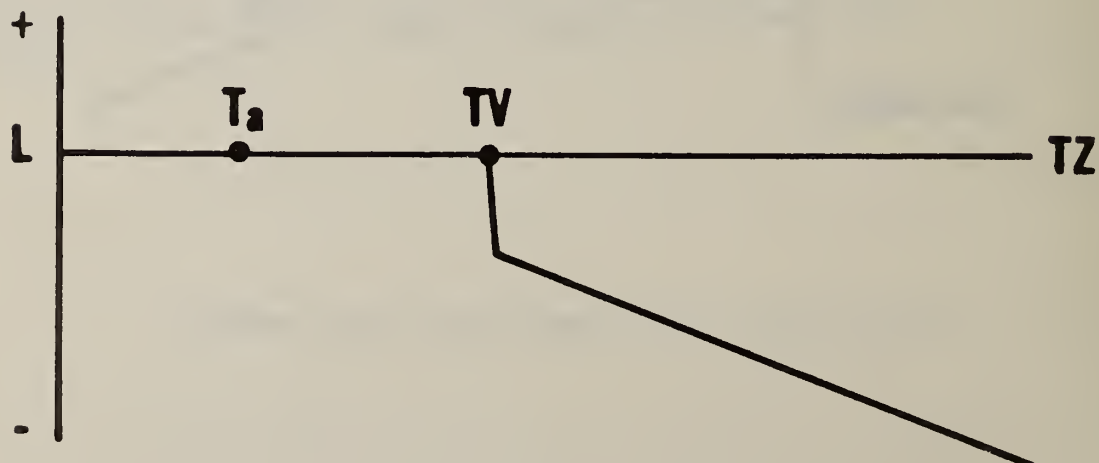


Figure III.K.3 Ventilation control profile: T_a higher than TV

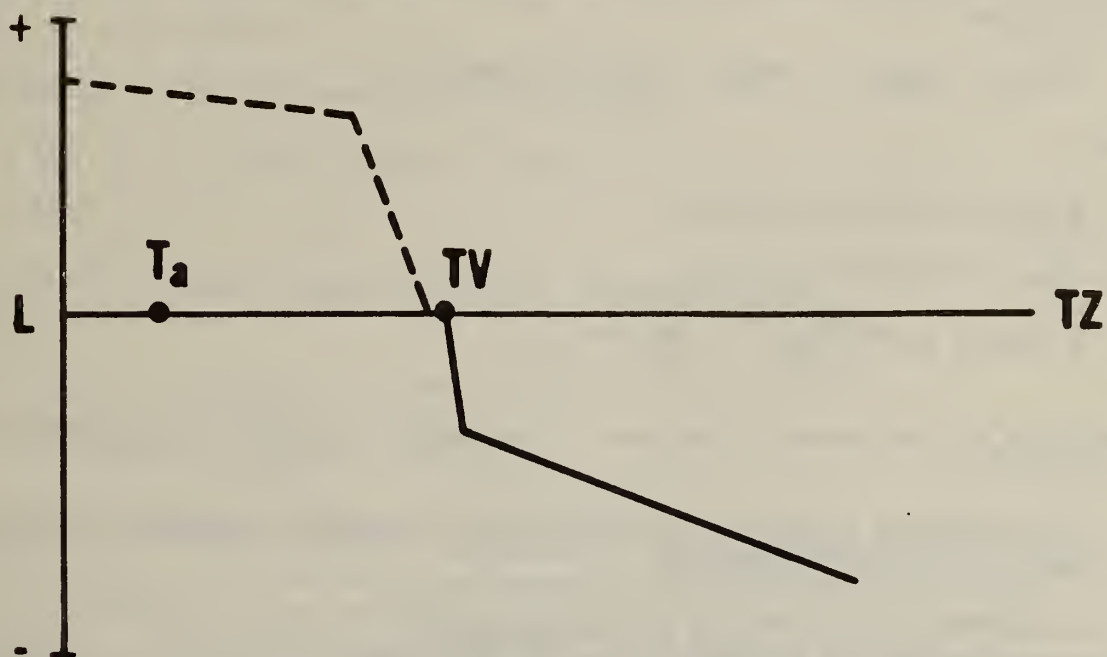


Figure III.K.4 Ventilation and heating control profiles

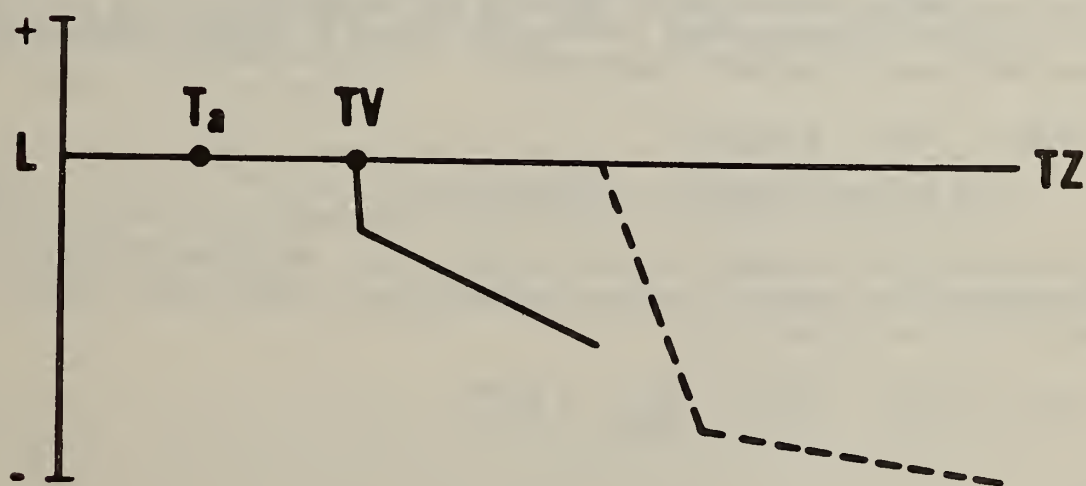


Figure III.K.5 Ventilation and cooling control profiles

III.L HEAT BALANCE CONVERGENCE

In any zone the air temperature, mean radiant temperature, and the surface temperatures are intimately related. A change in any one will cause changes in all of the others. Those secondary changes should be predictable.

It was observed that, with the zone air temperature held nearly constant by a large heating capacity, there was a regular pattern in successive radiant temperature values during the heat balance iterations for a given hour.

$$(TR_{k+2} - TR_{k+1}) / (TR_{k+1} - TR_k) = \text{constant} \quad (\text{L.1.1})$$

where

k is the iteration number.

The value of that constant is

$$\Sigma (HR_1 * S_1 * \frac{\partial TI_1}{\partial TR_n}) / \Sigma (HR_1 * S_1) \quad (\text{L.1.2})$$

with 1 for all surfaces of the zone. The partial derivatives are described in section J.

The following logic led to a method for improved convergence for fixed or floating zone air temperature.

- (1) Do the first iteration in the normal manner.
- (2) During the second iteration a new TR is computed (H.2.5). It is ΔTR_0 greater (negative value means less) than the first iteration TR.
- (3) By itself, this would cause an increase of $\alpha * \Delta TR_0$ in the value of TR in the next iteration. α is the constant given by (L.1.2).
- (4) It also causes an increase in the zone air temperature due to increased convective gain. Assuming that the average change in surface temperatures equals the change in radiant temperature

$$\Delta TZ_0 = \Delta TR_0 * \Sigma HC_1 * S_1 / [\Sigma HC_1 * S_1 + \Sigma F_j * C_p - (1-\beta) * LT] \quad (\text{L.1.3})$$

- (5) Increasing TZ will then increase the TI because of convective gain. Again assuming the change in surface temperatures is about equal to the change in radiant temperature

$$\Delta TR_1 = \Delta TZ_0 * \Sigma HC_1 * S_1 * \frac{\partial TI_1}{\partial TZ_n} / \Sigma HC_1 * S_1$$

$$\begin{aligned}
&= \Delta TR_0 * \Sigma HC_i * S_i * \frac{\partial TI_i}{\partial TZ_n} / \\
&[\Sigma HC_i * S_i + \Sigma F_j * C_p - (1-\beta)LT] \\
&= \gamma * \Delta TR_0
\end{aligned} \tag{L.1.4}$$

(6) Combine the changes in radiant temperature in (3) and (5) to give the total change in TR for one iteration.

$$\Delta TR_2 = (\alpha + \gamma) * \Delta TR_0 \tag{L.1.5}$$

The total change in TR over several iterations is

$$\begin{aligned}
\Delta TR &= \Delta TR_0 * [1 + (\alpha + \gamma) + (\alpha + \gamma)^2 + (\alpha + \gamma)^3 + \dots] \\
&= \Delta TR_0 / (1 - \alpha - \gamma)
\end{aligned} \tag{L.1.6}$$

(7) Similarly, the total change in zone air temperature is given by

$$\begin{aligned}
\Delta TZ &= [\Delta TR_0 * \Sigma HC_i * S_i] * [(\alpha + \gamma) + (\alpha + \gamma)^2 + \dots] / \\
&[\Sigma HC_i * S_i + \Sigma F_j * C_p - (1-\beta)LT]
\end{aligned} \tag{L.1.7}$$

(8) The current estimates of TR and TZ are therefore increased by ΔTR and ΔTZ , respectively. Then the surface temperatures and resulting new zone air temperature are calculated in the normal manner. For the convergence test the new TZ is compared to the predicted value of TZ instead of the previous iteration value. If the two temperatures (or associated heating/cooling load) are sufficiently close, the solution has converged.

On the first iteration of a given hour, many parameters may have changed from the previous hour. These parameters include the delayed conductive gains and radiant and scheduled loads. These are additional factors which must be included in the convergence algorithm. So far that has only been partially successful.

Sample results of the convergence improvement algorithm for a single zone showed a reduction from an average of 7.6 to 2.3 iterations per hour in the floating temperature mode and from 5.4 to 2.1 iterations per hour in the fixed temperature mode.

IV. INPUT

IV.A OVERVIEW

It is intended that the TARP input deck be an on-line file which is created and modified by a text editing system. It can also be a deck of punched cards. There is a simple, consistent input structure. The input is based on a keyword system (keyword = value) to produce a free-format, self-descriptive input. In some ways it is similar to NAMELIST input which is a feature of some versions of FORTRAN. The keywords have been kept short (usually less than 5 letters) to reduce the amount of typing that must be done. The keyword system is organized in a logical hierarchy which groups related concepts and data. Defaulting is used extensively. This applies to individual values and to groups of values representing entire elements of building operation or description. Some groups of often used data can be named and then used many times by referring to the name.

This input method was chosen from the following four basic alternatives.

1. Columns or lines of numbers for simple fixed or free format FORTRAN reading.
2. A free-format, self-descriptive language such as used by BLAST or DOE.
3. A prompting, fully interactive system.
4. A graphic, interactive system.

Method 4 could not be used because of its equipment and programming time requirements. The complexity of describing building geometry may make it the logical choice of input for a user-oriented loads program. Simple FORTRAN reads (method 1) are easy to program and produce a small, fast computer program. However, it is difficult to incorporate simple defaulting and optional input. It is also difficult to understand and correct the input without running it through the input processor. Self-descriptive input (method 2) can be criticised as taking too long to prepare and presenting more opportunities for error because of the additional words used to describe the numbers. But defaulting is easy to incorporate, and the user can understand the input deck directly after only a little practice. Prompting, interactive input (method 3) can be of great help to the beginning user. The large number of values involved in a complete building description can make full prompting tedious. The prompting system must allow for changing the input after it has been used for a loads calculation. This method may be worth the programming time it would take to implement.

IV.B INPUT LANGUAGE SYNTAX

Several goals were assisted by the development of a simple, consistent input structure. That input structure may be considered a language and the relationships of the components of a language are called "syntax". The following pages describe the input syntax in two ways. First is the Backus-Naur Form (BNF) which is traditional to computer science. Second is

an English description of the same features for those who are unfamiliar with BNF.

IV.B.1 BNF DESCRIPTION

1. $\langle \text{INPUT DECK} \rangle ::= \langle \text{SECTION} \rangle \{ \langle \text{SECTION} \rangle \}$
2. $\langle \text{SECTION} \rangle ::= \langle \text{SECTION NAME} \rangle [\langle \text{KEY} \rangle \{ \langle \text{KEY} \rangle \}]$
3. $\langle \text{KEY} \rangle ::= \langle \text{KEY NAME} \rangle (\langle \text{SUBKEY} \rangle \{ \langle \text{SUBKEY} \rangle \})$
4. $\langle \text{SUBKEY} \rangle ::= \langle \text{SUBKEY NAME} \rangle / |$
 $\langle \text{SUBKEY NAME} \rangle = \langle \text{DATA} \rangle \{ , \langle \text{DATA} \rangle \} /$
5. $\langle \text{DATA} \rangle ::= \langle \text{NAME} \rangle | \langle \text{INTEGER} \rangle | \langle \text{REAL} \rangle | \langle \text{DATE} \rangle | \langle \text{DESCRIPTION} \rangle$
6. $\langle \text{NAME} \rangle ::= \langle \text{CHAR} \rangle \{ \langle \text{CHAR} \rangle | \langle \text{NULL} \rangle \}$
7. $\langle \text{UNS INTEGER} \rangle ::= \langle \text{DIGIT} \rangle \{ \langle \text{DIGIT} \rangle | \langle \text{NULL} \rangle \}$
8. $\langle \text{INTEGER} \rangle ::= \langle \text{UNS INTEGER} \rangle | - \langle \text{UNS INTEGER} \rangle$
9. $\langle \text{REAL} \rangle ::= \langle \text{INTEGER} \rangle | \langle \text{INTEGER} \rangle . | . \langle \text{UNS INTEGER} \rangle |$
 $\langle \text{INTEGER} \rangle . \langle \text{UNS INTEGER} \rangle |$
 $\langle \text{INTEGER} \rangle . \langle \text{UNS INTEGER} \rangle E \langle \text{INTEGER} \rangle$
10. $\langle \text{DATE} \rangle ::= \langle \text{MONTH} \rangle \langle \text{UNS INTEGER} \rangle | \langle \text{UNS INTEGER} \rangle \langle \text{MONTH} \rangle$
11. $\langle \text{DESCRIPTION} \rangle ::= ' \{ \langle \text{CHAR} \rangle | \langle \text{SYMBOL} \rangle | \langle \text{NULL} \rangle \} '$
12. $\langle \text{CHAR} \rangle ::= \langle \text{LETTER} \rangle | \langle \text{DIGIT} \rangle | - | .$
13. $\langle \text{SYMBOL} \rangle ::= / | = | , | (|) | \$ | * | [|]$
14. $\langle \text{NULL} \rangle ::= \langle \text{BLANK} \rangle | +$
15. $\langle \text{LETTER} \rangle ::= A | B | \dots | Y | Z$
16. $\langle \text{DIGIT} \rangle ::= 0 | 1 | \dots | 8 | 9$
17. $\langle \text{MONTH} \rangle ::= \text{JAN} | \text{FEB} | \dots | \text{NOV} | \text{DEC}$
18. $\langle \text{COMMENT} \rangle ::= \$ |) |] \{ \langle \text{CHAR} \rangle | \langle \text{SYMBOL} \rangle | \langle \text{NULL} \rangle \} \text{ END-OF-LINE}$

IV.B.2 ENGLISH DESCRIPTION

1. The TARP input deck consists of several sections. There are presently four sections: PROJECT, LIBRARY, BUILDING, and ZONE.
2. Each section consists of a section name and one or more keys enclosed in brackets.

3. A key is a key name and one or more subkeys enclosed in parentheses.
4. A subkey consists of a subkey name or a subkey name, an equals sign, one or more data values, and a terminating slash. When only a subkey name is called for, entry of that name enables some option. Most subkeys introduce one or more elements of data. Multiple data values are separated by commas.
5. There are five different data types. Only descriptions may be longer than 10 non-null characters.
6. A name consists of characters.
7. An unsigned integer consists of digits.
8. An integer is an unsigned integer for positive values or an unsigned integer preceeded by a minus sign for negative values.
9. There are five distinct representations for real numbers. Note that a decimal point is not necessary and that exponential notation is possible.
10. Dates consist of a month name and a day number.
11. A description is a string of characters and other symbols enclosed in apostrophes. It may be up to 100 characters long, including nulls and symbols. An apostrophe may not occur within the string.
12. "Characters" are letters, digits, hyphen (minus), and period.
13. There are several generally recognized symbols in FORTRAN 77. These symbols are used as punctuation in the input language. Most systems also provide other symbols which may be used in those language elements which use "symbols" such as ", %, @, etc.
14. The blank and plus sign are nulls. They are ignored by the input reader. Therefore, elements of the language may be separated by blanks to improve readability. The plus sign does not affect the value or character count of a number.
15. Letters are the 26 letters of the alphabet.
16. Digits are the 10 numerals.
17. Months are first three letter abbreviations of the 12 months.
18. Comments begin with a dollar sign or at the end of a key or end of a section and continue to the end of the line. They may be included on lines with input or on separate lines.

Other features:

Successive identical subkey values "...,<DATA>,<DATA>,<DATA>..." may be replaced by "...,<UNSIGNED INTEGER>*<DATA>..." .

A line of input may be up to 80 characters long. Input features may be continued on succeeding lines. Punctuation determines the end of all input features except comments, which terminate at the end of the line.

The final subkey slash before ending a section may be dropped. That is, "/")" may be replaced by ")". The slash may be considered a separator rather than a terminator.

IV.B.3 ERROR PROCESSING

The TARP handles incorrect input by reporting the error and then skipping to the next readable input. It makes no attempt to correct the input error. It is more important for the user to correctly type punctuation than names or values. The approximate order of importance of punctuation is: ' \$ [] () / = , . Similarly, section names are more important than key names which are more important than subkey names which are more important than data. For example, an incorrect data value would cause the program to not process only that value, but an incorrect subkey name causes the program to skip all values following it (because the program cannot know to which subkey they apply) and go to the next subkey; which will be after the next "/". Similarly, an incorrect key name causes the program to skip the entire key including all its subkeys. The key name will have to be corrected and another run made to find any errors in the subkeys. The punctuation is critical because it determines where the input skipping stops. The program must then find a recognizable name or another skip will occur. Thus the brackets and parentheses are more important than slashes because an error in them causes more skipped input. The apostrophe and dollar sign are most critical because descriptions and comments can include punctuation symbols which could totally confuse the input reader. Although this process sounds complex, the consistency of the syntax makes it very easy for the user to check punctuation before submitting the input to the computer. The input deck can be debugged in a small number of runs because the entire deck will be processed during every run instead of quitting at the first error.

IV.C INPUT DETAILS

The input must be made meaningful by defining the "vocabulary" of names and data which fill in the syntax. Every section, key, and subkey is discussed below. Each subkey description is headed by a line containing six elements:

1. The section, key, and subkey numbers (e.g. 2.4.1). These serve in cross-referencing to other input. Several related subkeys may be grouped under one subkey number.
2. The subkey name, "=", data types. The data types mean: n = name, r = real, i = integer, d = date, desc = description.
3. The default. Dimensional values are in metric units. Immediately below is the value in English units.
4. The units. "-" means dimensionless. English units are given below the metric units.
5. The status. "reqd" means a value must be given. "opt" means a value is optional; otherwise the default will be used. "cond" means conditional. One of several values must be chosen or a value must be chosen if some other input has been set.
6. The permitted range of the data value.

IV.C.1 PROJECT SECTION

1. PROJECT [Project Section.
This section is required. It also must be first. It creates the data that relates to the entire project: weather data and various input/output controls.
- 1.1 RC (Run control parameters.
This key is optional, but if it is used it must be first.
- 1.1.1 DESC = 'desc' blank - opt -
This description will appear on the loads reports.
- 1.1.2 SYNTAX no - opt -
This subkey causes the input processor to do only a "syntax check". Syntax and typing errors are listed. This avoids many of the calculations that are normally done, so that the processor can run quicker and with less core, but it does not produce a simulation input file (SINPFL) for the loads program.
- 1.1.3 DEM no - opt -
This subkey will enable the printing of more detailed error messages. It may be useful in the early debug phase or for the inexperienced user.

- 1.1.4 2SPC no - opt -
This will cause double spacing. A blank line will be inserted between each user input line which is echoed in the input processor report. This enhances readability.
- 1.1.5 XREF no - opt -
The input processor will report the sequence number of every major input element. This will aid in locating the input that may be causing errors in the loads calculation. See V.A.2.3 for further details.
- 1.1.6 OLDW no - opt -
This subkey may be used if a environment file (ENVTFIL) has been prepared and saved in a previous run. It causes keys 1.3, 1.4, 1.5, and 1.6 to be skipped, saving the time that would be spent preparing a new identical environment file.
- 1.1.7 ENGLISH yes - opt -
METRIC
UIN = n
UOUT = n
These subkeys provide different ways of specifying the units used for the input and output of numbers. See the Table of Units. ENGLISH means the input and output are in English units. METRIC means they are in metric units. Alternatively, the input units can be either UIN=ENGLISH or UIN=METRIC and the outputs either UOUT=ENGLISH or UOUT=METRIC.
- 1.2 RPT (Set reports flags.
- 1.2.1 RNOS = 1,1,... 9 - opt -
1 = dump PROJECT and LIBRARY data
2 = dump DDY and WTAP data
3 = dump CTF calculations
4 = dump glass calculations
5 = dump DSS data
6 = dump ZONE data
7 = dump cross reference values
8 = dump SINPFL as read by loads program
9 = report description of zone
13 = report sunlit areas
14 = report shadowing combinations
15 = dump shadow calculation controls
16 = dump shadow calculations
20 = dumps 21-24 during warm-up period
21 = dump primary zone data
22 = dump constant load components
23 = dump variables
24 = dump temperature and flux histories
25 = dumps 21-24 on WED nearest 21st of month

- 1.3 LOC (Location.
- 1.3.1 DESC = 'desc' blank - opt -
- 1.3.2 LATD = r 40. degrees opt -90.<=r<=90.
The latitude of the site. Degrees north is positive.
- 1.3.3 LONG = r 90. degrees opt -180.<=r<=180.
The longitude of the site. Degrees west is positive.
- 1.3.4 TZ = r 6. - cond 0.<=r<=24.
The time zone number of the site. The United States eastern time zone is 5 and the Pacific time zone is 8.
- 1.3.5 ALT = r 0. - opt -
The altitude of the site. Not used by the program.
- 1.3.6 TER = 1 2 - opt 1<=1<=3
Type of terrain is used only with HO = 2 (3.1.6).
Type numbers are as described in III.B.4.
- 1.4 GRND (Ground parameters.
- 1.4.1 GRT = r,r,...<12> 12*12.78 C opt -
12*55. F
- Ground temperatures for the 12 months starting with January. They are used only with other side coefficients (4.3).
- 1.4.2 MWT = r,r,...<12> 12*12.78 C opt -
12*55. F
- Make-up water temperatures for the 12 months starting with January.
Not yet used by the program.
- 1.5 WTAP (Weather tape parameters.
- 1.5.1 DESC = 'desc' blank - opt -
- 1.5.2 SKIP = 1 0 - opt 0<=1<=365
Skip this number of days on the weather tape before starting to process days for the environment file (ENVTFIL).
- 1.5.3 DAYS = 1 365 - opt 1<=1
Process this number of days from the weather tape (WTHRTP) to the environment file (ENVTFIL).
- 1.6 DDY (Design day description.
- 1.6.1 DESC = 'desc' blank - opt -

1.6.2 HIGH = r 35.0 C opt -
95.0 F

High temperature for the design day.

1.6.3 LOW = r 22.78 C opt LOW<=HIGH
73.0 F

Low temperature for the day.

1.6.4 WB = r 25.56 C opt -
78.0 F

Wet bulb temperature at the time of the day's high temperature. This temperature must be psychrometrically possible.

1.6.5 DATE = d 21JUL - opt -

The date determines the solar position and length of daylight.

1.6.6 PRES = r 100000. Pa opt -
401.5 in H2O

The absolute barometric pressure at the site is used in the psychrometric calculations.

1.6.7 WS = r 3.353 m/s opt -
660. ft/min

The default wind speed is 7.5 miles per hour. (1 mph = 88 ft/min)

1.6.8 DIR = r 270. degrees opt -360.<=r<=360.

Wind direction: north = 0 degrees, clockwise is positive. The default wind is from the west.

1.6.9 CLR = r 1.0 - opt 0.<=r

The total solar radiation on a horizontal surface is the ASHRAE clear sky amount times this clearness number. The proportion of beam and diffuse radiation changes according to a correlation function.

1.6.10 RAIN no - opt -

RAIN causes the outside temperatures of surfaces exposed to ambient to be set to the wet bulb temperature. This models the cooling effect of rain on the building.

1.6.11 SNOW no - opt -

SNOW causes the ground reflectance to be increased from its default of 0.2 to 0.7. This gives a much higher diffuse solar gain to the zones.

1.6.12 SUN ... MON - opt -

The day of the week determines which day-schedules (2.2) and control day-schedules (2.6) are used. Allowable day names are: SUN, MON, TUE, WED, THU, FRI, SAT, HOL, SP1, SP2, SP3, SP4.

IV.C.2 LIBRARY SECTION

2. LIBRARY [Library Section.

The library simplifies input by grouping relatively large amounts of data by name. That name can be referenced later in the input process instead of again specifying all the data. This produces economies when items are used several times. There are seven types of library data: day-schedules (DS), week-schedules (WS), materials (MATL), constructs (CONS), control profiles (CPFL), control day-schedules (CDS), and control week-schedules (CWS).

2.1 LIB (Library control parameters.

2.1.1 NAME = n blank - opt -
Not yet used.

2.1.2 NDS = 1 16 - opt -
NWS = 1 16 - opt -
NMATL = 1 16 - opt -
NCONS = 1 16 - opt -
NCPFL = 1 16 - opt -
NCDS = 1 16 - opt -
NCWS = 1 16 - opt -

These subkeys control the number of library elements which can be defined. Library names are stored in an array which is 256 elements long. The total number of named library elements cannot exceed 256. The sum of these subkeys (including those left to default) cannot exceed 256.

2.1.3 ALL no - opt -
DS no - opt -
WS no - opt -
MATL no - opt -
CONS no - opt -
CPFL no - opt -
CDS no - opt -
CWS no - opt -

These eight subkeys control the printing of library data. The eight individual names will each produce reports for that class of library data. ALL will cause all eight classes to be reported.

2.2 DS (Day-schedules.

A day-schedule is a set of 24 numbers used to provide an hourly variation in some building parameter.

2.2.1 NAME = n blank - reqd -

Each day-schedule name must be different from all other day-schedule names.

- 2.4.4 CP = r .8368 kJ/kg*K cond 0.<r
0.2 Btu/lbm*F
Specific heat.
- 2.4.5 D = r 0. kg/m³ cond 0.<r
0. lbm/ft³
Density.
- 2.4.6 R = r 0. m²*K/W cond 0.<r
0. hr*ft²*F/Btu
Thermal resistance (R-value).
- 2.4.7 A = r .75 - opt 0.<=r<=1.
Absorptance (and emittance) for solar radiation.
- 2.4.8 E = r .90 - opt 0.<r<1.
Emittance (and absorptance) for thermal wavelength radiation.
- 2.4.9 TRNS = r 0. - opt 0.<r<1.
Transmittance of GLASS (2.4.17) and SHADE (2.4.16) materials.
- 2.4.10 IR = r 1.52 - opt 1.<r<2.
Index of refraction of GLASS (2.4.17) materials.
- 2.4.11 FTRN = r 0. - opt 0.<r<1.
This is the transmittance of a sheet of GLASS (2.4.17) with a thin metallic film on the inside surface.
It must be used in conjunction with TRNS (2.4.9) which is the transmittance of the glass without the film.
FTRN must be less than TRNS.
The thickness of the film is computed from those values and IR (2.4.10) with optical properties of aluminum assumed for the film.
- 2.4.12 REF = r 0. - opt 0.<r<1.
Reflectance of a SHADE (2.4.16)
- 2.4.13 SC = r 0. - opt 0.<r<1.14
The ASHRAE defined shading coefficient of a window. This must be used with GLASS (2.4.17). All other optical properties are ignored.
- 2.4.14 RGH = 1 2 - opt 1<=i<=6
The roughness index interacts with the wind speed to determine the outside convection coefficient. Index values:
1 very rough - stucco, built-up roof with stone, wood shingles
2 rough - brick, plaster, concrete block
3 medium rough - concrete, asphalt, shingles
4 medium smooth - clear pine
5 smooth - smooth plaster or metal
6 very smooth - glass, smooth painted surfaces

2.4.15 AIR - - cond -

This subkey must be used if the material is to be used as an air layer in any transparent construct. The optical algorithms assume that the glass panes are separated by air layers. Those air layers automatically have TRNS=1 and IR=1.

2.4.16 SHADE - - cond -

This indicates that the material is an interior shade in transparent constructs. It must have information on TRNS (2.4.9) and REF (2.4.12). Conductive properties need not be defined because they will not be used.

2.4.17 GLASS - - cond -

This subkey indicates the glass panes in a transparent construct. A GLASS material must have conductive properties and optical properties chosen from: (TRNS, IR) or (TRNS, IR, FTRN) or (SC). The program assumes that multiple panes are separated by air layers for the optical calculations.

2.5 CONS Constructs.

Constructs are the wall and window sections, described in terms of their constituent layers, that make up the building.

2.5.1 NAME = n blank - reqd -

Every construct must have a name different from all other constructs.

2.5.2 DESC = 'desc' blank - opt -

A description will appear in the construct report to more fully describe the construct.

2.5.3 MATL = r,n,r,n,... 0,blank m, - reqd -
ft, -

This subkey describes the material layers which form the construct. The values are pairs of (thickness, name of material) from the outside to the inside layer. Layers which are described by R-value (2.4.6) must be given a thickness to maintain the proper sequence of values. The value of that thickness is not used in the conductivity calculations, so even a zero is adequate.

2.5.4 OA = r - - opt $0 \leq r \leq 1$.

Outside absorptance (and emittance) for solar radiation. If no value is given, the default is the absorptance (2.4.7) of the outside (first) layer.

2.5.5 OE = r - - opt $0 \leq r \leq 1$.

Outside emittance (and absorptance) for thermal radiation. If no value is given, the default is the emittance (2.4.8) of the outside (first) layer.

- 2.5.6 ORGH = i - - opt $1 \leq i \leq 6$
 This describes the roughness of the outside surface. It has the values of subkey 2.4.14. If no value is given, the default is the roughness of the outer layer.
- 2.5.7 IA = r - - opt $0 \leq r \leq 1$.
 Inside absorptance (and emittance) for solar radiation. If no value is given, the default is the absorptance (2.4.7) of the inside (last) layer.
- 2.5.8 IE = r - - opt $0 \leq r \leq 1$.
 Inside emittance (and absorptance) for thermal radiation. If no value is given, the default is the emittance (2.4.8) of the inside (last) layer.
- 2.6 CPFL (Control profiles.
 Control profiles relate the capacity of the air handling system to the zone temperature.
- 2.6.1 NAME = n blank - reqd -
 Every control profile must have a unique name.
- 2.6.2 DESC = 'desc' blank - opt -
 The description more fully describes the control profile.
- 2.6.3 TMP = r,r,... - C reqd -
 F
 This subkey is a list of the control point temperatures which make up the control profile. See IV.E on control profiles.
- 2.6.4 CAP = r,r,... - - reqd $-1 \leq r \leq 1$.
 This subkey is a list of the control point capacities which make up the control profile.
 Each capacity is matched to the control temperature (2.6.3).
 There may be no more than eight capacities in the profile.
 See IV.E on control profiles.
- 2.7 CDS (Control day-schedules.
 A control day-schedule is a set of 24 control profiles.
- 2.7.1 NAME = n blank - reqd -
 Each control day-schedule name must be different from all other control day-schedule names.
- 2.7.2 DESC = 'desc' blank - opt -
 A description will more fully describe the purpose of the control day-schedule. It will appear in the day-schedule report.
- 2.7.3 CPFL = n,n,... blank - reqd -
 24 profile names are required: one for each hour of the day. They must have been previously defined (2.6).

CWS (Control week-schedules.

A control week-schedule is a set of 12 control day-schedules: one for each day of the week, one for holidays, and one for each of 4 special day types (SP1, SP2, SP3, and SP4). It is referenced by name in subsequent building input.

2.8.1	NAME = n	blank	-	reqd	-
-------	----------	-------	---	------	---

Each control week-schedule must have a name different from all other control week-schedule names.

```
2.8.2  DESC = 'desc'      blank - opt -
```

A description is useful in more fully describing the schedule, but its use is optional.

2.8.3 WD = n blank - cond -

Set weekday (Monday through Friday) pointers to the named control day-schedule. That control day-schedule must have been previously defined (2.7). Other options are:

WE = n Set weekend (SAT & SUN) pointers.

ALL = n Set all 12 pointers.

SUN = n Set Sunday pointer only

MON = n Set Monday pointer only.

and similarly for TUE = n, WED = n, THU = n, FRI = n, SAT = n, SP1 = n, SP2 = n, SP3 = n, and SP4 = n. At least one day must be defined (other pointers will be set by default rules).

IV.C.3 BUILDING SECTION

3. BUILDING [Building Section.
This section describes features referring to all zones of the building.
The entire section is optional. If used, it must occur before any zone
(section 4.) descriptions.
- 3.1 SIM (Simulation control parameters.
If this key is used, it must occur before any detached shadowing
surfaces (3.2). It may not be used more than once.
- 3.1.1 N = r 0.0 degrees opt -360.<=r<=360.
Degrees from true north to the north axis of building coordinate system
(IV.F.5).
Clockwise is positive.
- 3.1.2 SLDS = i 0 - opt 0<=i<=3
Solar distribution algorithm:
0 = shading from 'SHD' surfaces only;
1 = shading from 'SHD' and 'DSS' surfaces;
2 = shading from all surfaces including other zones;
3 = 2 + distribution of beam radiation on interior surfaces.
The surfaces of each zone must form a simple convex envelope.
- 3.1.3 CNVG = r,r,r,i .056,.01,.1,6 C,-,W,- opt -
.1,.01,.34,6 F,-,Btu/hr,-
Heat balance iteration convergence limits:
First variable = temperature convergence: when there is no heating or
cooling load successive iterations of zone air temperature must be
within r degrees.
Second variable = loads convergence: when there is a load, successive
iterations of loads must be $(1 - \text{load}(n)/(\text{load}(n-1))) < r$.
Third number = minimum load: when $\text{load}(n) < r$, the next iteration
would cause division by a small number. Therefore convergence is
assumed. Convergence is also assumed if $|\text{load}(n) - \text{load}(n-1)| < r$.
Fourth number = maximum number of iterations. Then record occurrence of
non-convergence and go to next time step.
It is not necessary to give all 4 numbers, but to set the third number
the first two must also be given.
- 3.1.4 FLOW = i 12 - opt 0<i
This subkey indicates that the loads processor will use the detailed
air flow algorithm (III.G). It may be used without the value. The
value specifies the maximum number of iterations: Run terminates if
this number is exceeded because the heat balance is not valid if the
flows are not balanced. Two other air flow convergence parameters
are set as functions of the heat balance parameters (3.1.3).
Relative flow convergence = relative loads convergence.
Absolute flow convergence = .00005 * minimum load.

- 3.1.5 HTB = i 0 - opt i = 0, 1, or 2
Solve surface heat balances using only a single calculation of the outside surface temperature (0 or 1) or by iterating the outside temperatures simultaneously with the inside surface temperatures to convergence (2). The simpler mean radiant temperature (H.2.3) is used with HTB = 0 and the more detailed MRT (H.2.H) is used with 1 or 2.
- 3.1.6 HO = i 0 - opt i = 0 or 2
Compute exterior convection coefficient using simple (0) or detailed (1) algorithm (I.1 and I.2).
- 3.1.7 HI = i 0 - opt i = 0 or 1
Compute interior convection coefficient using simple (0) or detailed (2) algorithm (J.1 and J.2).
- 3.2 DSS (Detached shadowing surfaces.
Shadows from these surfaces are not used unless SLDS > 0 (3.1.2).
- 3.2.1 AZM = r 0 degrees opt -360.<=r<=360.
Azimuth (facing) angle of surface relative to building coordinate system. For example, north = 0, east = 90, south = 180, west = 270 or -90.
- 3.2.2 TILT = r 90 degrees opt 0.<=r<=180.
Tilt of surface (0 = facing upward like flat roof; 90 = vertical; 180 = facing downward like floor).
- 3.2.3 X = r 0. m opt -
0. ft
Y = r 0. m opt -
0. ft
Z = r 0. m opt -
0. ft
ORG = r,r,r
Coordinates of lower left corner of surface relative to building coordinate system. ORG provides a simpler way of describing all 3 coordinates at once (ORG = X, Y, Z) . See IV.F on geometric data.
- 3.2.4 W = r 0. m reqd -
0. ft
H = r 0. m reqd -
0. ft
SIZE = r,r
or
VRTS = r,r,r,r or r,r,r,r,r,r

The first two forms specify the width and height of a rectangular surface (SIZE = W, H). The last form is for triangles or quadrilaterals. The first pair of numbers are the surface relative x-y coordinates of the first vertex counter-clockwise from the lower left vertex. The subsequent pairs of numbers are the coordinates

of the remaining vertices in counterclockwise sequence. See IV.F on geometric data.

3.2.5 TRNS = r 0. - opt 0.<r<=1.

Transmittance of the shadowing surface.

3.2.6 FROM = d 1JAN - opt -
 THRU = d 31DEC

The surface may apply for only part of the year. Any dates may be used, but for greatest efficiency dates should be chosen from the shadowing surface dates table.

IV.C.4 ZONE SECTION

4. ZONE [Zone Section.
A zone is a space under the control of one thermostat (or uncontrolled) where the air can be considered well mixed. The zone is composed of surfaces which connect it to the environment or to other zones, scheduled internal loads, and air temperature control strategy. There may be multiple zone sections. They must appear after the PROJECT, LIBRARY, and BUILDING sections.

4.1 GEOM (Zone geometry.
This key is required and must be the first key in the zone section. It may not be used more than once.

4.1.1 NAME = n blank - reqd -
Each zone must have a unique name.

4.1.2 N = r 0.0 degrees opt -360.<=r<=360.
Degrees from building north axis to north axis of zone coordinate system. Clockwise is positive.

4.1.3 X = r 0. m opt -
0. ft
Y = r 0. m opt -
0. ft
Z = r 0. m opt -
0. ft

ORG = r,r,r
Coordinates of the lower left corner of the zone relative to the building coordinate system. ORG provides a simpler way of describing all 3 coordinates at once (ORG = X, Y, Z). See IV.F on geometric data. Zone origin is necessary only for the more detailed shadowing calculations (SLDS > 0; sec 3.1.2).

4.1.4 CLHT = r 3.0 m opt -
9.84 ft
Height of ceiling is used only in computing the zone height for detailed air flow calculations (3.1.4 and G.2).

4.1.5 MIRX no - opt -
This key causes all surface x-vertices to be mirrored about the y-axis (north-south axis).

4.1.6 MIRY no - opt -
This key causes all surface y-vertices to be mirrored about the x-axis (east-west axis).

4.2 PEO (Occupant heat gains.

4.2.1 WS=n - - reqd -
The occupancy schedule is selected from the library of week-schedules (2.3). The hours refer to clock time.

- 4.2.2 CAP = r 0 - cond 0.<r
Enter the number of occupants.
- 4.2.3 ACT = r 0.1318 kW opt .102<=r<=.425
.450 kBtu/hr .35<=r<=1.45
Enter the activity level. The program will divide this number into latent and sensible portions based on room air temperature.
- 4.2.4 RAD = r .5 - opt 0.<=r<=1.
This is the fraction of the sensible heat gain which is radiated to the room surfaces. The rest is convected to the room air.
- 4.2.5 FROM = d 1JAN - opt -
THRU = d 31DEC - opt -
The occupancy week-schedule may apply for only part of the year. The schedule used by another PEO key may not overlap.
- 4.3 LIT (Heat gains from lights.
The total heat gain from lights is divided into several fractions and each is handled differently. The convective fraction is 1.-RA-RAD-VIS. It may not be less than zero.
- 4.3.1 WS = n - - reqd -
The total lighting energy is modified by the week-schedule element (2.3) for the appropriate day and hour (clock time).
- 4.3.2 CAP = r 0. kW reqd 0.<r
0. kBtu/hr
CAP is the peak power consumption (capacity) of the zone lights.
- 4.3.3 RA = r 0. - opt 0.<=r<=1.
This is the fraction of the total lighting energy which goes directly into the return air instead of into the zone. This can occur with vented light fixtures.
- 4.3.4 RAD = r .20 - opt 0.<=r<=1.
This is the fraction which can be considered long-wave radiant energy. It interacts with zone surfaces according to their inside emittance (2.5.8). The default fraction is typical of flourescent lights. A value of 0.80 is appropriate for incandescent lights.
- 4.3.5 VIS = r .20 - opt 0.<=r<=1.
This is the fraction which can be considered short-wave (or visible) radiant energy. It interacts with the room surfaces according to their inside absorptance (2.5.7). It can leave the zone through transparent surfaces without creating a load. The default is typical of flourescent lights. For incandescent lights 0.10 is an appropriate value.
- 4.3.6 REP = r 0. - opt -
This is the fraction of lighting energy which can be replaced by daylight (4.10).

4.3.7 FROM = d 1JAN - opt -
 THRU = d 31DEC - opt -

The lighting week-schedule may be applied to only part of the year. The schedules used by other LIT keys may overlap. This allows a simple way to combine lighting from different sources as might be necessary to describe area and task lighting.

4.4 EQP (Heat gains from equipment.

EQP describes the heat gains from various types of equipment. The convective fraction of that gain is 1.-LAT-RAD-LOST. It may not be less than zero.

4.4.1 WS = n - - reqd -

The equipment is selected from the library of week-schedules (2.3). The schedule refers to clock time.

4.4.2 CAP = r 0. kW reqd 0.<r
 0. kBTU/hr

CAP is the peak power consumption of the equipment. A negative capacity is permitted. It can describe a process which cools the zone. A zero capacity is meaningless.

4.4.3 LAT = r 0. - opt 0.<=r<=1.

This is the latent fraction, i.e., the fraction of energy used to add water vapor to the zone air.

4.4.4 RAD = r .3 - opt 0.<=r<=1.

This is the radiant fraction which is treated as long-wave radiation.

4.4.5 LOST = r 0. - opt 0.<=r<=1.

The fraction lost allows the user to add energy to the total zone and building consumption without effecting the zone loads. For example, it might be used to account for outside lighting.

4.4.6 FROM = d 1JAN - opt -
 THRU = d 31DEC - opt -

Time periods for multiple EQP keys may overlap.

4.4.7 EL - - cond -

	electricity	
GS	gas	cond
ST	steam	cond
HW	hot water	cond
OTHR	other	cond

These simple subkeys identify the energy source of the equipment. They allow summing of the building energy requirements by energy type. One of them must be given. OTHR allows a load to occur in the zone without adding to the energy requirements.

4.5 INF (Simple infiltration - Algorithm K.2.

INF allows scheduling of infiltration with simple temperature and wind

speed dependencies. It may not be used with the detailed air flow option (3.1.4).

4.5.1 WS = n - - reqd -
The infiltration schedule is selected from the library of week-schedules (2.3). The schedule refers to clock time.

4.5.2 CAP = r 0. m^3/s reqd 0.<r
0. ft^3/min

Enter the peak infiltration volume flow rate. The user must convert "air changes" to volume flow rate.

4.5.3 C = r .606 - opt -
T = r .03636 1/C opt -
.0202 1/F
V = r .1177 s/m opt -
.000598 min/ft
VV = r 0. $(\text{s/m})^2$ opt -
0. $(\text{min/ft})^2$

The scheduled infiltration is modified by the factor:
 $(C + T*|TZ - TA| + V*SPD + VV*SPD^2)$

where TZ = zone air temperature

TA = ambient air temperature

SPD = wind speed

The default values are for a 7.5 mph wind and 0 temperature difference.

Users who wish to have a constant infiltration should set C to 1 and the other coefficients to 0.

4.5.4 FROM = d 1JAN - opt -
THRU = d 31DEC - opt -

Time periods from multiple INF keys may not overlap.

4.6 VENT (Ventilation - Algorithm K.3.
Ventilation describes the use of unconditioned outside air to cool the zone. It may also be used to precool the zone during unoccupied hours. It may not be used with the detailed air flow option (3.1.4).

4.6.1 WS = n - - reqd -
The ventilation schedule is chosen from the library of week-schedules (2.3). The schedule refers to clock time.

4.6.2 CAP = r 0. m^3/s reqd 0.<r
0. ft^3/min

Enter the peak volumetric flow rate.

4.6.3 MIN = r 20. C opt -

This causes ventilation to seek to bring the zone air temperature down to the value given. If this subkey is used, do not use MAX (4.6.4).

- 4.6.4 MAX = r 90. C opt -
 This causes ventilation to occur whenever the zone air temperature is greater than this value. If this subkey is used, do not use MIN (4.6.3).
- 4.6.5 TD = r 2. K opt 0.<=r
 3.6 F
 This requires that the outside air be TD degrees cooler than the inside air before ventilation can occur.
- 4.6.6 FROM = d 1JAN - opt -
 THRU = d 31DEC - opt -
 Time periods of multiple VENT keys may not overlap.
- 4.7 MIX (Two zone mixing - Algorithm K.4.
 MIX simulates the controlled mixing of two zones such as occurs in attached sunspace designs. It may not be used with the detailed air flow option (3.1.4).
- 4.7.1 WS = n - - reqd -
 The mixing schedule is chosen from the library of week-schedules (2.3). The schedule refers to clock time.
- 4.7.2 CAP = r 0. m³/s reqd 0.<r
 0. ft³/min
 Enter the peak volumetric flow rate. The mass flow will be based on standard (1.2kg/m³) air.
- 4.7.3 TD = r 0. K opt 0.<=r
 0. F
 There is mixing with the adjacent zone whenever the zone air temperature is TD greater than the adjacent zone. When TD is zero, there is always mixing (as controlled by the schedule).
- 4.7.4 ZONE = n - - reqd -
 Give the name of the adjacent zone.
- 4.7.5 FROM = d 1JAN - opt -
 THRU = d 31DEC - opt -
 Time periods of multiple MIX subkeys may not overlap.
- 4.8 FAN (Whole house fan - Algorithm K.5.
 Fan simulates a whole house fan which exhausts house air into the attic. It may not be used with the detailed air flow option (3.1.4).
- 4.8.1 WS = n - - reqd -
 The fan schedule is chosen from the library of week-schedules (2.3). The schedule refers to clock time.

- 4.8.2 CAP = r 0. m^3/s reqd 0.<r
 0. ft^3/min
 Enter the peak volumetric flow rate. The mass flow will be based on standard (1.2kg/m³) air.
- 4.8.3 T = r 0. C reqd 0.<=r
 0. F
 The FAN will seek to cool the zone air temperature to T.
- 4.8.4 ZONE = n - - reqd -
 Give the name of the adjacent (attic) zone.
- 4.8.5 FROM = d 1JAN - opt -
 THRU = d 31DEC - opt -
 Time periods of multiple FAN subkeys may not overlap.
- 4.9 CTRL (Zone control - Algorithm K.1.
 Details of zone temperature control are described in IV.E.
- 4.9.1 CWS = n - - reqd -
 The control schedule is selected from the library of control week-schedules (2.8). The control profile is referenced by clock time.
- 4.9.2 HEAT = r 1.E6 kW opt 0.<=r
 Enter the peak heating capacity.
- 4.9.3 COOL = r 1.E6 kW opt 0.<=r
 Enter the peak cooling capacity.
- 4.9.4 RAD = r 0. - opt 0.<=r<1.
 The control profile refers to a control temperature which is defined as (1-RAD)*TZ + RAD*TR where TZ is the zone air temperature and TR is the zone mean radiant temperature.
- 4.9.5 FROM = d 1 JAN - opt -
 THRU = d 31DEC - opt -
 It is common to operate with different control profiles during different seasons as heating or cooling capacities are shut off. The time periods from multiple CTRL keys may not overlap.
- 4.10 DLT(Daylighting.
 The program uses a very simple model to estimate the savings in lighting energy by using daylighting. All DLT keys should appear in the zone description before any LIT keys.
- 4.10.1 WS = n - - reqd -
 The fraction of beam sunlight which is usable for lighting is modified by the week-schedule (2.3) element for the hour (standard time).

4.10.2 BEAM = r 0. - opt 0.<=r<=1.

This is the fraction of beam sunlight entering the zone which can be used to offset the visible energy from the lights.

4.10.3 DIFF = r 0. - opt 0.<=r<=1.

This is the fraction of diffuse sunlight entering the zone which can be used to offset the visible energy from lights.

4.10.4 FROM = n 1 JAN - opt -
THRU = d 31DEC - opt -

Time periods from multiple DLT keys may not overlap.

4.11 BBH (Baseboard heat.

This key describes a system which adds heat to the zone based on the outside air temperature.

4.11.1 WS = n - - reqd -

The peak heating capacity available at any hour (clock time) is modified by the baseboard heating schedule selected from the week-schedule library (2.3).

4.11.2 CAP = r,r 0.,0. kW reqd 0.<=r

The first value is the peak heating capacity. The second value is the minimum heating capacity at the shut-off temperature. Two values are required.

4.11.3 TMP = r,r 0.,0. C reqd -

The first value is the highest temperature at which the system gives full heating capacity. The second value is the maximum temperature for which the system produces any heat (the shut-off temperature). Both values are required.

4.11.4 RAD = r .3 - opt 0.<=r<=1.

This is the radiant fraction which is treated as long-wave radiation.

4.11.5 FROM = d 1JAN - opt -
THRU = d 31DEC - opt -

Time periods from multiple BBH keys may not overlap.

4.11.6 ST - - cond -
HW - - cond -

These refer to the source of heating energy: steam or hot water. One or the other must be given.

4.12 MASS (Internal mass.

Internal masses are modeled by the internal surface algorithms. The only difference from the treatment of a partition is that the internal mass is not given a location in the zone and, therefore, beam sunlight cannot fall directly on it.

4.12.1 CONS = n - - reqd -
 Select the composition of the mass from the constructs library (2.5)
 (2.5).

4.12.2 AREA = r 0. m² reqd 0.<r
 0. ft²

The mass must be given an area.

4.13 SRF (Heat transfer surfaces.
 All zone surfaces which conduct or store heat (except internal mass;
 4.12) are described by this key.

4.13.1 CONS = n - - reqd -
 Select the composition of the surface from the constructs library
 (2.5).

4.13.2 EX - - cond -
 IN - - cond -
 OP - - cond -
 TR - - cond -
 BS - - cond -
 SS - - cond -

The user must specify the following three factors: Is this an EXterior or INTERior surface? Is the surface OPaque or TRansparent? Are its coordinates defined as a Base Surface or a SubSurface? (The coordinates of a subsurface are defined relative to the most recently described base surface.) There are eight combinations of these factors. Three of those are not permitted because of various algorithmic restrictions in the program. The following table explains the three factors in terms of the common English names for such surfaces (at three basic tilt angles).

EX/IN	OP/TR	BS/SS	90 deg	0 deg	180 deg
EX	OP	BS	wall	roof	-
EX	OP	SS	door	-	-
EX	TR	BS	*** not permitted ***		
EX	TR	SS	window	skylight	-
IN	OP	BS	partition	ceiling	floor
IN	OP	SS	*** not permitted ***		
IN	TR	BS	-	-	-
IN	TR	SS	*** not permitted ***		

4.13.3 AZM = r 180. degrees opt -360.<=r<=360.
 Azimuth (facing) angle of the surface relative to the zone coordinate system. North = 0; clockwise positive. This is used for base surfaces only. Subsurfaces face the same direction as their base surface.

4.13.4 TILT = r 90. degrees opt 0.<=r<=180.
 Tilt of surface (0 = facing upward like flat roof; 90 = vertical; 180 = facing downward like floor). This is used for base surfaces only. Subsurfaces have the same tilt as their base surface.

4.13.5 W = r 0. m reqd 0.<r
 0. ft
 H = r 0. m reqd 0.<r
 0. ft

 SIZE = r,r

 VRTS = r,r,r,r or VRTS = r,r,r,r,r,r

The first two forms specify the width and height of a rectangular surface (SIZE = W, H). The last form is for triangles or quadrilaterals. The first pair of numbers are the surface relative x-y coordinates of the first vertex counter-clockwise from the lower left vertex. The subsequent pairs of numbers are the coordinates of the remaining vertices in counter-clockwise sequence. See IV.F on geometric data.

4.13.6 X = r 0. m opt -
 0. ft
 Y = r 0. m opt -
 0. ft
 Z = r 0. m opt -
 0. ft

 ORG = r,r,r

For base surfaces (BS - 4.13.2) these are the coordinates of the lower left corner of the surface relative to the zone coordinate system. The base surface origin is not used in the simple shadow calculation mode (3.1.2). For subsurfaces (SS - 4.13.2) these are the coordinates relative to the lower left corner of the base surface. The Z coordinate is the amount of the setback. ORG provides a simpler way of describing all three coordinates at once (ORG = X, Y, Z) . See IV.F on geometric data.

4.13.7 FSS = r .5 - opt 0.<=r<=1.

FSS is the angle factor between the surface and the sky. It is used in determining the intensity of diffuse sky radiation incident on the surface. If FSS is not specified, it is computed from the TILT (4.13.4) angle: $FSS = (1 + \cos(\text{tilt}))/2$.

4.13.8 FSG = r .5 - opt 0.<=r<=1.

FSG is the angle factor between the surface and the ground. It is used in determining the intensity of diffuse ground reflected radiation on the surface. If FSG is not specified, it is computed from the tilt (4.13.4) angle: $FSG = (1 - \cos(\text{tilt}))/2$.

4.13.9 ZONE = n blank - opt -

This is the name of the zone on the other side of the surface from the current zone. The program will check for that zone to have a surface which refers to this zone. That is, a single partition (or ceiling or floor) which is between two zones, must be described in each zone. The program checks that these two surfaces have the same area and U-value. It makes a partial check on the conduction transfer functions. Remember that constructs are defined from the outer to the inner layer and, therefore, asymmetric interzone partitions will have to be defined twice to be referenced from the different zones.

4.14 AFS (Air flow surface - Algorithm G

AFS describes the crack area and other openings in the base surface which are used in the detailed air movement simulation. FLOW (3.1.4) must have been specified. The base surface must be either an exterior surface or an interzone surface (4.13.2 and 4.13.9). The AFS assumes the azimuth of the base surface for computing wind direction effects. When the AFS applies to an interzone surface, there must be an identical AFS specified for the appropriate base surface in the adjacent zone.

4.14.1 AREA = r 0. m² reqd 0.<r
0. ft²

This is the effective area of the opening.

4.14.2 EXP = r .65 - opt .5≤r≤1.

EXP is the flow exponent. It is typically .65 for exterior walls and .50 for interzone openings.

4.14.3 ZS = r - m opt -
- ft

This is the height of the centroid of the surface or opening relative to the zone origin (G.2). The default value is the average of the heights of the vertices of the base surface.

4.14.4 ZT = r - m opt -
- ft

This is the height at which the wind speed is evaluated for the opening (G.1). The default value is the highest vertex of the base surface.

4.15 SHD (Shadowing subsurfaces.

SHD describe simple shadowing surfaces which apply to the most recently defined base surface (BS - 4.13.2) and all of its subsurfaces. The base surface must be an exterior (EX) surface unmodified by OSC (4.16).

4.15.1	OHNG	-	-	cond	-
	LFIN	-	-	cond	-
	RFIN	-	-	cond	-
	PROJ	-	-	cond	-

There are four configurations for these features: overhang, left fin, right fin, and projection. See IV.F for details.

4.15.2	W = r	0.	m	reqd	0.<=r
		0.	ft		
	H = r	0.	m	reqd	0.<=r
		0.	ft		

SIZE = r,r

These subkeys specify the width and height of the rectangular shadowing surface. SIZE is a shorter description (SIZE = W, H) . See IV.F on geometric data.

4.15.3	X = r	0.	m	opt	-
		0.	ft		
	Y = r	0.	m	opt	-
		0.	ft		
	Z = r	0.	m	opt	0.<=r
		0.	ft		

ORG = r,r,r

The positioning of the shadowing subsurface is given relative to the base surface coordinate system. See IV.F on geometric data.

4.15.4	TRNS = r	0.	-	opt	0.<=r<1.
--------	----------	----	---	-----	----------

Transmittance of the shadowing surface.

4.15.5	FROM = d	1JAN	-	opt	-
	THRU = d	31DEC	-	opt	-

The surface may apply for only part of the year. Any dates may be used, but for greatest efficiency dates should be chosen from the shadowing surface dates table (IV.G.1).

4.16 OSC (Other side coefficients.

OSC provides a means of approximating conditions on the outside of a surface where it is not desirable (or possible) to simulate those conditions. The OSC key applies to the most recently described surface. That surface should be EX / OP / BS (4.13.2). It should also have no shadowing or heat transfer subsurfaces. Other side coefficients establish an outside temperature which is a function of several factors. The temperature is computed from the formula:

$$T = (TZP \cdot TZ + TAP \cdot TA + CTP \cdot CT + TGP \cdot GRT + WSP \cdot SPD \cdot TA) / (TZP + TAP + TGP + WSP \cdot SPD)$$

where TZ = most recent value of zone air temperature

TA = ambient air temperature

GRT = ground temperature (1.4.1)

SPD = wind speed

and the other factors are user defined as described below. At least one of the factors in the divisor of the equation must be defined nonzero.

4.16.1	HO = r	0.	W/m ² K	opt	0.<=r
		0.	Btu/hr*ft ² F		

This is the value of the outside surface convection coefficient. If it is zero, the OSC temperature is the surface outside temperature. If it is not zero, The OSC temperature is an air temperature which is used with the convection coefficient to compute the outside surface temperature.

4.16.2	TZP = r	0.	-	opt	-
--------	---------	----	---	-----	---

Zone temperature part.

4.16.3	TAP = r	0.	-	opt	-
--------	---------	----	---	-----	---

Ambient air temperature part.

4.16.4	CT = r	0.	C	opt	-
		0.	F		

Constant temperature.

4.16.5	CTP = r	0.	-	opt	-
--------	---------	----	---	-----	---

Constant temperature part.

4.16.6	TGP = r	0.	-	opt	-
--------	---------	----	---	-----	---

Ground temperature part.

4.16.7	WSP = r	0.	s/m	opt	-
		0.	min/ft		

Wind speed part.

4.17 EMI (Exterior movable insulation.

Exterior movable insulation is applied to the most recently defined surface. That surface must have been defined as exterior (EX; 4.13.2) and not modified by subsequent OSC (4.16). EMI may apply to either massless or massive surfaces. EMI is opaque and can prevent solar gains through windows.

4.17.1	CONS = n	-	-	reqd	-
--------	----------	---	---	------	---

The movable insulation is chosen from the constructs library. The movable insulation algorithm handles only massless insulation. It uses the U-value, outer solar and thermal absorptances and roughness of the construct.

4.17.2	DS = n	-	-	cond	-
	SNUP	-	-	cond	-
	SNDN	-	-	cond	-

One of three methods must be chosen for control of the EMI. The first is reference to a day-schedule (2.2). A value of zero means no EMI for that hour (standard time) and a one means the EMI is in effect.

Fractional values in the day-schedule modify the R-value. Any schedule value greater than zero causes sunlight to be absorbed on the EMI rather than on the surface. Second is SNUP which means the EMI is in effect whenever the sun is above the horizon. SNDN means the EMI is in effect when the sun is below the horizon.

4.17.3	FROM = d	1JAN	-	opt	-
	THRU = d	31DEC	-	opt	-

The EMI may apply for only part of the year. It may be desirable to use different controls during different seasons. Any dates may be used, but since the EMI effects the solar gain calculations, dates should be chosen from the table of shadowing surface dates (IV.G.1) for greatest efficiency. Time periods from multiple EMI subkeys may not overlap.

4.18 IMI (Interior movable insulation.
 Interior movable insulation applies to interzone surfaces only. That is, the most recently defined surface should be interior (IN; 4.13.2) and have an other side zone name (4.13.9).

4.18.1 CONS = n - - reqd -
 The movable insulation is chosen from the constructs library. The movable insulation algorithm handles only massless insulation.

4.18.2 DS = n - - cond -
 GAIN - - cond -
 LOSS - - cond -

One of three methods must be chosen for control of the IMI. First is reference to a day-schedule (2.2). A value of zero means no IMI for that hour (clock time) and a one means the IMI is in effect. Fraction values in the day-schedule modify the R-value. The second method is GAIN which causes the IMI to be in effect whenever the surface temperature is greater than the zone control temperature (4.9.4). LOSS is the inverse of the GAIN operation.

4.18.3 FROM = d 1JAN - opt -
 THRU = d 31DEC - opt -

Since IMI does not effect the zone's solar gain, the dates need not refer to the shadowing surface dates. Time periods from multiple IMI subkeys may not overlap.

IV.D INPUT SUMMARY

This summary of the input language is intended to serve as a reminder of the syntax and all the keywords. As the user becomes more familiar with the input, he will use this summary more and the detailed input description (IV.C) less. It may be desirable to copy these pages and place them near the computer terminal.

Data types:

n = name, r = real, i = integer, d = date, desc = description

1. PROJECT [

- 1.1 RC (DESC = 'desc' / SYNTAX / DEM / 2SPC / XREF / OLDW /
ENGLISH / METRIC / UIN = n / UOUT = n)
 - 1.2 RPT (RNOS = i,...)
 - 1.3 LOC (DESC = 'desc' / LATD = r / LONG = r / TZ = r / ALT = r /
TER = i)
 - 1.4 GRND (GRT = r,...<12> / MWT = r,...<12>)
 - 1.5 WTAP (DESC = 'desc' / SKIP = i / DAYS = i)
 - 1.6 DDY (DESC = 'desc' / HIGH = r / LOW = r / WB = r / DATE = d /
PRES = r / WS = r / DIR = r / CLR = r / RAIN / SNOW /
SUN / MON / TUE / WED / THU / FRI / SAT /
HOL / SP1 / SP2 / SP3 / SP4)
-]

2. LIBRARY [

- 2.1 LIB (NAME = n / NDS = i / NWS = i / NMATL = i / NCONS = i /
NCPFL = i / NCDS = i / NCWS = i / ALL / DS /
WS / MATL / CONS / CPFL / CDS / CWS)
- 2.2 DS (NAME = n / DESC = 'desc' / FFC = r,...<24>)
- 2.3 WS (NAME = n / DESC = 'desc' / WD = n / WE = n / ALL = n /
SUN = n / MON = n / TUE = n / WED = n / THU = n / FRI = n /
SAT = n / HOL = n / SP1 = n / SP2 = n / SP3 = n / SP4 = n)
- 2.4 MATL (NAME = n / DESC = 'desc' / K = r / CP = r / D = r /
R = r / A = r / E = r / TRNS = r / IR = r / FTRN = r /
REF = r / SC = r / RGH = i / AIR / SHADE / GLASS)
- 2.5 CONS (NAME = n / DESC = 'desc' / MATL = r,n,r,n,...<10> /
OA = r / OE = r / ORGH = i / IA = r / IE = r)

2.6 CPFL (NAME = n / DESC = 'desc' / TMP = r,...<8> / CAP = r,...<8>)

2.7 CDS (NAME = n / DESC = 'desc' / CPFL = n,...<24>)

2.8 CWS (NAME = n / DESC = 'desc' / WD = n / WE = n / ALL = n /
SUN = n / MON = n / TUE = n / WED = n / THU = n / FRI = n /
SAT = n / HOL = n / SP1 = n / SP2 = n / SP3 = n / SP4 = n)
]

3. BUILDING [

3.1 SIM (N = r / SLDS = i / CNVG = r,r,r,i / FLOW = i /
HTB = i / HO = i / HI = i)

3.2 DSS (AZM = r / TILT = r / X = r / Y = r / Z = r / ORG = r,r,r /
W = r / H = r / SIZE = r,r / VRTS = r,...<4 or 6> /
TRNS = r / FROM = d / THRU = d)
]

4. ZONE [

4.1 GEOM (NAME = n / N = r / X = r / Y = r / Z = r / ORG = r,r,r /
CLHT = r / MIRX / MIRQ)

4.2 PEO (WS = n / CAP = r / ACT = r / RAD = r / FROM = d / THRU = d)

4.3 LIT (WS = n / CAP = r / RA = r / RAD = r / VIS = r / REP = r /
FROM = d / THRU = d)

4.4 EQP (WS = n / CAP = r / LAT = r / RAD = r / LOST = r /
FROM = d / THRU = d / EL / GS / ST / HW / OTHR)

4.5 INF (WS = n / CAP = r / C = r / T = r / V = r / VV = r /
FROM = d / THRU = d)

4.6 VENT (WS = n / CAP = r / MIN = r / MAX = r / TD = r /

FROM = d / THRU = d)

4.7 MIX (WS = n / CAP = r / TD = r / ZONE = n / FROM = d / THRU = d)

4.8 FAN (WS = n / CAP = r / T = r / ZONE = n / FROM = d / THRU = d)

4.9 CTRL (CWS = n / HEAT = r / COOL = r / RAD = r / FROM = d /
THRU = d)

4.10 DLT (WS = n / BEAM = r / DIFF = r / FROM = d / THRU = d)

4.11 BBH (WS = n / CAP = r,r / TMP = r,r / RAD = r / FROM = d /
THRU = d / ST / HW)

- 4.12 MASS (CONS = n / AREA = r)
- 4.13 SRF (CONS = n / EX / IN / OP / TR / BS / SS / AZM = r / TILT = r /
W = r / H = r / SIZE = r,r / VRTS = r,...<4 or 6> / X = r /
Y = r / Z = r / ORG = r,r,r / FS = r / FSG = r / ZONE = n)
- 4.14 AFS (AREA = r / EXP = r / ZS = r / ZT = r)
- 4.15 SHD (OHNG / LFIN / RFIN / PROJ / W = r / H = r /
SIZE = r,r / X = r / Y = r / Z = r / ORG = r,r,r /
TRNS = r / FROM = d / THRU = d)
- 4.16 OSC (HO = r / TZP = r / TAP = r / CT = r / CTP = r / TGP = r /
WSP = r)
- 4.17 EMI (CONS = n / DS = n / SNUP / SNDN / FROM = d / THRU = d)
- 4.18 IMI (CONS = n / DS = n / GAIN / LOSS / FROM = d / THRU = d)
]

IV.E ZONE TEMPERATURE CONTROL

The zone air temperature is determined by the interaction of the energy flows in the zone and the operation of the air conditioning system. The present version of the TARP does not include detailed system models. The operation of the system is modeled by control profiles like those in the loads section of the BLAST program [1] from which much of the following discussion is taken. A control profile relates the zone air temperature to the capability of the system to add or remove heat from the zone. The use of the control profile in the zone air heat balance is described in III.K.1. Figure E.1 shows a simple control profile which can either heat or cool the zone.

Point 1 might occur on a winter day. At that point, the room is at 68 F (20.0 C) and the heat loss from the room air exactly equals the room heating capacity available at 68 F. In this example, the room heating load (= heat delivered to the room air) is 40.0 kBtu/hr (11.7 kW).

Point 2 might occur on a mild day in the spring or fall. At this point (73 F [22.8 C]), no room heating or cooling is accomplished by the building fan system (although heating or cooling energy may be consumed to condition ventilation air). For the heat balance to occur at point 2, convective heat gains caused by such factors as lights or occupancy must be balanced by convective heat losses to room surfaces or by infiltration. The load at point 2 is zero.

Point 3 shows a cooling condition. Here heat gains to the room air are balanced by cooling capacity available at the balance point temperature.

The control profile can be described in terms of the temperatures and heating/cooling capacities at control points A, B, C, and D. Simple linear proportionality is assumed between the control points. At temperatures below point A, the heating capacity is constant. The cooling capacity is constant above point D. The control profile is described in two phases in TARP. The full heating and cooling capacities are given for each zone (4.9.2 and 4.9.3). The shape of the profile is described in the library section by normalizing the control point capacities (divide heating capacities by the full heating capacity; divide cooling capacities by the full cooling capacity, the result being set negative). This allows the same profile to be used in many zones which have identical control temperatures but different full capacities. Full heating and cooling capacities can then be adjusted independently of each other. The control profile in figure E.1 normalizes to that in figure E.2 which could be described by the input language (2.6) as:

```
CPFL ( NAME=C1 / TMP=67,69,77,79 / CAP=1,0,0,-1 )
```

The temperatures and capacities of the control points must be given in the sequence shown. Very steep profiles are possible. The user may set two successive control temperatures equal to each other to hold the room temperature constant. TARP will make the second 0.01 C greater than the first to permit the air heat balance calculations.

System type can subtly affect room temperature control profiles. For example, assume that a package DX (direct expansion) condensing unit with electric heat has been selected to serve the zone whose control strategy is shown in figure E.1. Further assume that the unit delivers 3850 cfm ($1.82 \text{ m}^3/\text{s}$) to the space, that the cooling coil was selected to allow 55 F (12.8 C) air to be delivered at the design sensible load of 100 kBtu/hr (29.3 kW), and that the heating coil was selected to deliver 86.2 F (30.1 C) air at the design heating load of 80 kBtu/hr (23.4 kW). In this case, figure E.1 closely approximates the achieved room temperature control. The room thermostat will modulate the condensing unit from "off" to "full" capacity through as many capacity control steps as are available on the unit. This modulation will occur in a roughly linear fashion as the balance point room temperature varies from 77 to 79 F (25 to 26.1 C). The heating will be similarly modulated between 69 and 67 F (20.6 and 19.4 C), and both heating and cooling will be "off" between 69 and 77 F (20.6 and 25 C). Since the condensing unit's maximum heating and cooling capacity are approximately constant, the unit adds or removes fixed quantities of heat whenever the room temperature is below 67 F (19.4 C) or above 79 F (26.1 C).

If a single-zone drawthrough unit served by hot and chilled water is selected, the control strategy of figure E.1 may require a slight revision. When room temperature remains between 67 and 79 F (19.4 and 26.1 C), figure E.1 is correct. However, as long as the boiler and chiller serving the coils in the fan unit can deliver constant temperature hot and chilled water, the maximum capacity of the heating and cooling coils is not independent of room temperature. For example, as the room temperature rises toward 79 F (26.1 C), the room thermostat opens the cooling coil's chilled water valve until the valve is fully opened at 79 F (26.1 C). If room heat gains are sufficient, the room air temperature will continue to rise; but as it rises, the temperature of the air entering the coil also rises. Therefore, the cooling capacity of the coil gradually increases. The capacities below point A and above point D of figure E.1 are not constant, but are slowly increasing. Coil catalog data can be used to determine the change in coil capacity.

Figure E.3 shows the equivalent control profile that should be used if a three-deck multizone unit is selected to serve several zones with the same thermostat throttling ranges and deadband. The rationale for selecting this profile is:

1. Range C-D is the thermostat deadband in which air delivered to the zone passes through the bypass deck and is neither heated nor cooled.
2. In range B-C, air from the hot deck and the bypass deck of the fan system are mixed to meet zone heating requirements. This is the heating throttling range for the thermostat. At its lower end (67 F [19.4 C]), all air to the zone comes through the hot deck and is delivered to the zone at the hot deck temperature (86.2 F [30.1 C], for example).

3. If heat losses are severe, the room temperature may fall into range A-B. In this range, air entering the room comes from the hot deck only. As long as the fan system heating coil is not overloaded, the air is supplied to the zone at constant temperature. However, the amount of heat added to the room air continues to increase as the room air temperature falls. The amount of heat added per hour can be calculated from the following formula:

$$L = F * C_p * (T_s - T_Z)$$

where

F = mass flow rate of air supplied by the fan system to the room

C_p = specific heat of air

T_s = supply air temperature to the room (the hot deck temperature)

T_Z = air temperature in the room

For this system, F and C_p are constant and T_s is constant for range A-B. Therefore, as room temperature (T_Z) falls, the heat added to the room increases linearly as shown in figure E.3.

4. Ranges D-E and E-F are analogous to ranges B-C and A-B, but are for cooling.

The TARP description of the profile in figure E.3 is:

CPFL (NAME=C2 / TMP=60,67,69,77,79,85 / CAP=1,.73,0,-0,-.8,-1)

When defining a control profile like the one shown in figure E.3, users should select arbitrary low and high room temperatures to establish the full heating and cooling (+1 and -1) points on the profile. In the example above, 60 and 85 F (15.6 and 29.4 C) were selected. When specifying corresponding heating and cooling capacities for each zone, the "design" capacity generally should not be used. Capacity should correspond with the selected low and high temperatures.

In the DX condensing unit, single-zone drawthrough, and three-deck multizone examples, load calculations will yield identical results when the control profiles shown in figures E.1 or E.3 are used, provided that the temperature in the space stays between 67 and 79 F (19.4 and 26.1 C) during the hours when the control profile is in effect. Fortunately, most systems are designed with sufficient capacity to maintain comfort conditions, and users need be concerned about room temperature control characteristics which are outside the range of the thermostat only when the heating or cooling system has been inadvertently or deliberately undersized.

The same reasoning used for the three-deck multizone system can be used to construct control profiles for spaces served by conventional multi-zone, dual duct, or reheat systems (see figure E.4). Ranges A-B and C-D correspond to ranges A-B and E-F of figure E.3, respectively. Range B-C covers the temperature range where the mixing box, zone dampers, or reheat coils are modulated by the room thermostat. The TARP description of such a profile is:

CPFL (NAME=C3 / TMP = 60,73,77,85 / CAP = 1,.58,-.74,-1)

No deadband is possible with these profiles so they cannot be approximated by profiles of the type shown in figures E.1 and E.3.

Figure E.5 shows a typical control profile for a VAV (variable air volume) system with reheat. It was constructed based on the assumption that 3850 cfm (1.82 m³/s) of 55 F (12.8 C) delivery air is to be supplied to the zone with the VAV dampers fully open at 79 F (26.1 C). The dampers close to 20 percent of full flow at 77 F (25 C). Reheat is to operate between 69 and 67 F (20.6 to 19.4 C), and the reheat coil will deliver air at 140 F (60 C) when fully energized. The following temperatures and capacities define the control profile:

Temperature F (C)	Capacity kBtu/hr(kW)	Normalized Capacity
60.0 (15.6)	66 (19.3)	1.0
67.0 (19.4)	61 (17.9)	.91
69.0 (20.6)	-12 (-3.5)	-.09
77.0 (25.0)	-18 (-5.3)	-.15
79.0 (26.1)	-100(-29.3)	-.80
85.0 (29.4)	-125(-36.6)	-1.0

The TARP input for this profile is:

CPFL (NAME=C4 / TMP=60,67,69,77,79,85 / CAP=1,.91,-.09,-.15,-.8,-1)

REFERENCES

- [1] Hittle, D. C., BLAST, Version 2.0: Users Manual, Vol 1, U. S. Army Construction Engineering Research Laboratory, Technical Report E-153 (Champaign IL, 1979), pp 41-46.

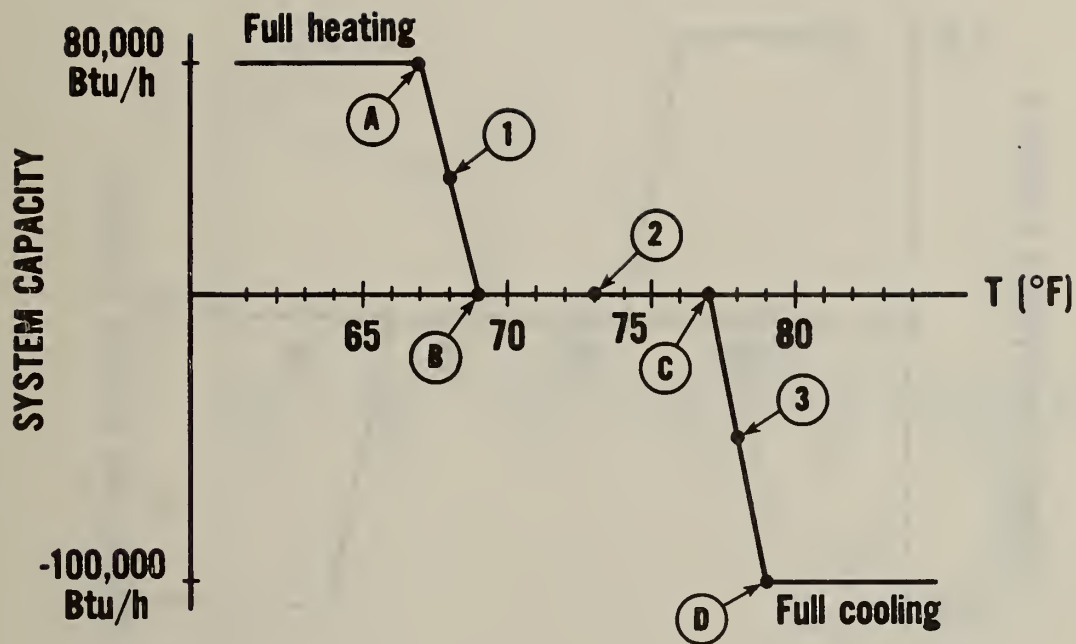


Figure IV.E.1 Simple control profile with deadband

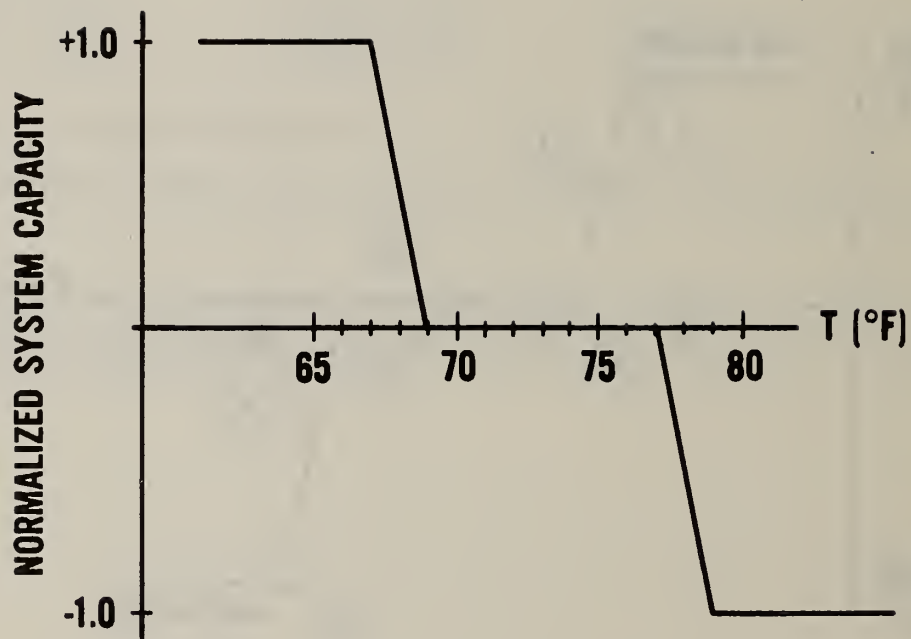


Figure IV.E.2 Normalized control profile

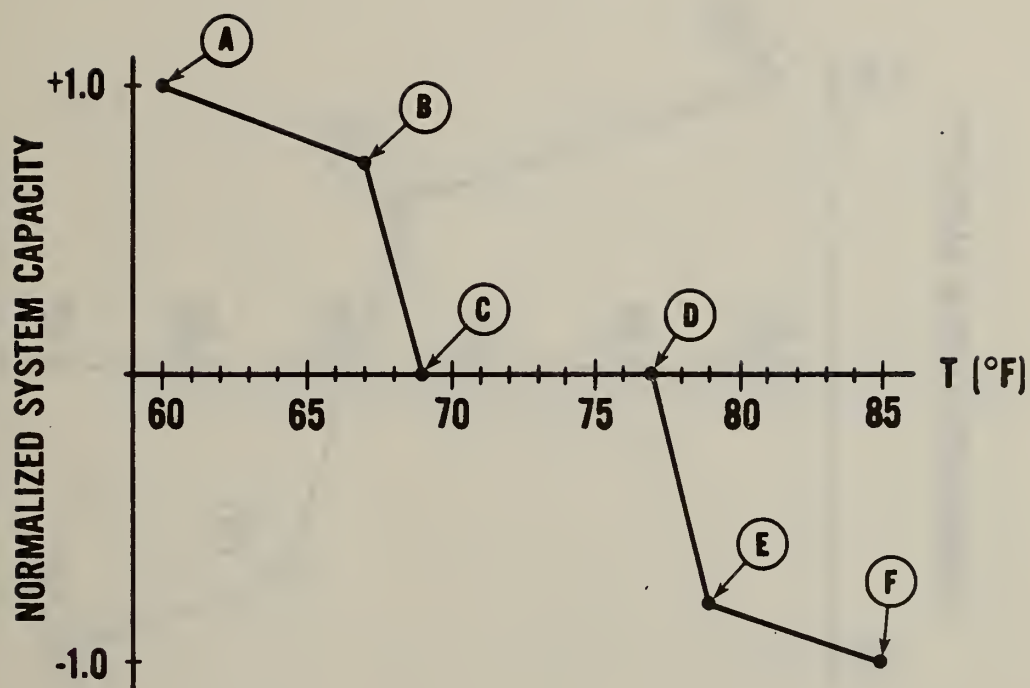


Figure IV.E.3 Control profile for three-deck multizone system

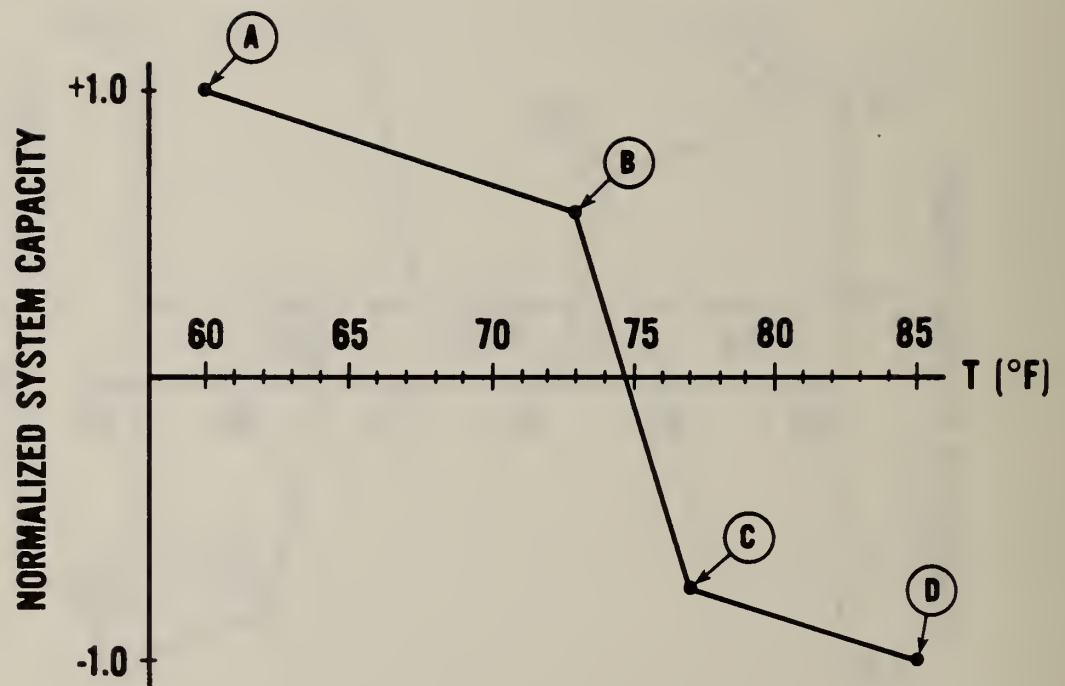


Figure IV.E.4 Control profile for multizone system

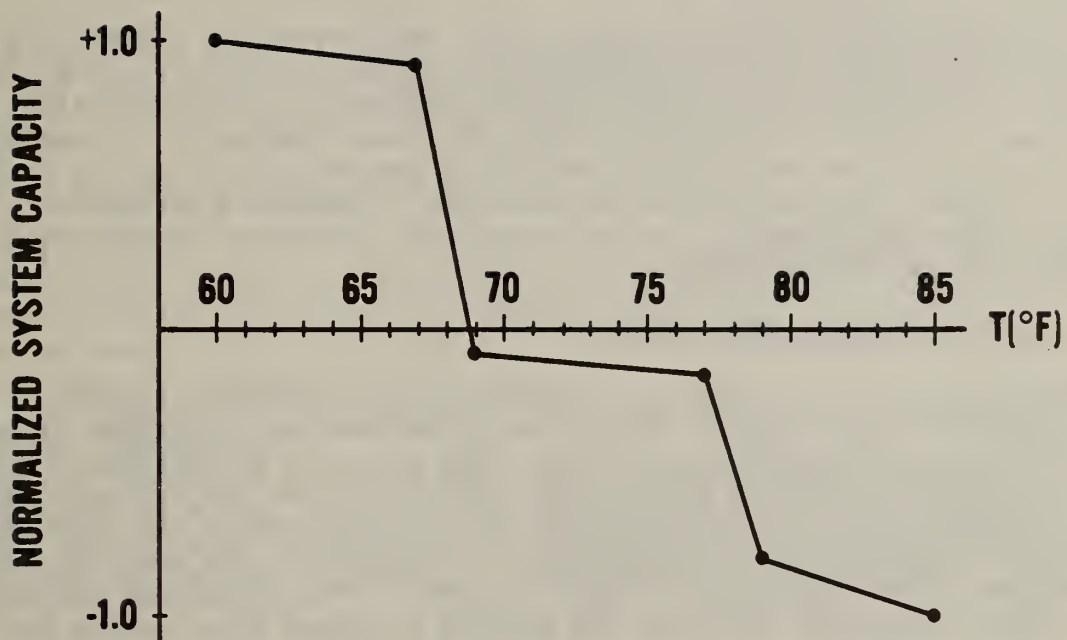


Figure IV.E.5 Control profile for VAV system

IV.F GEOMETRIC DATA

To accurately account for shading, solar gains, and the effects of wind on exterior walls, windows, and roofs, a fairly detailed description of the building's geometry is required. Every building surface is represented by a plane polygon of three or four sides. Within the program, each polygon is represented by the locations of its vertices in a simple Cartesian coordinate system. In that system, the X axis points due east, the Y-axis points north, and the Z-axis points upward. The orientation of each surface is maintained by two conventions. First, the vertices are stored in counter-clockwise sequence as the surface is viewed from outside the zone it encloses. (Looking at the surface from the opposite side would give a clockwise sequence.) Second, the orientation is described in terms of the "azimuth" and "tilt" angles.

The simplest level (0) of shadowing detail (3.1.2) requires that only the azimuth and tilt angles be specified. Detailed air flow analysis (3.1.4) and the detailed exterior surface coefficient algorithm (3.1.6) require correct heights for every surface. The first and second levels of shadowing detail require that all surfaces of the building envelope be correctly positioned in the building coordinate system. The third level of shadowing detail requires that internal surfaces also be correctly positioned and that the zone is completely enclosed.

A hierarchy of coordinates systems exists to simplify the positioning of surfaces. The building coordinate system is a simple rotation from the true coordinate system which allows major building features to be aligned along the X-Y axes. There is a coordinate system for every zone which is located relative to the building system for simplifying the description of the zone geometry. Finally, each surface of the zone has a coordinate system for defining the size and shape of the surface and the location of subfeatures which apply only to that surface.

IV.F.1 SURFACE COORDINATE SYSTEM

Every wall, roof, or floor of a building is represented by a plane surface of three or four sides. The origin of the surface coordinate system is located at one of the surface vertices. The X-axis is a horizontal (relative to the global coordinate system) line in the plane of the surface. The Y-axis is perpendicular to the X-axis and also in the plane of the surface. The Z-axis is perpendicular to the surface. It is used in the descriptions of subsurfaces. The coordinates of the vertices of the surface are described in the surface coordinate system as the surface is viewed from outside its zone.

Input (4.13.5) allows a simple description of rectangular surfaces. For example a rectangular wall 12 feet wide by 8 feet high ($W=12$ / $H=8$ or equivalently $SIZE=12,8$) would be described by figure F.1. This representation of rectangles places the origin at the lower left corner so that all vertices are positive numbers.

Non-rectangular surfaces can also be described by giving the coordinates of the vertices. For example, VRTS=10,0,5,30 describes the triangle in figure F.2. Negative coordinates like VRTS=12,-3,7,7,-5,10 are also possible (figure F.3). In the description of non-rectangular surfaces, a vertex at the origin (0,0) is assumed. The remaining vertices are given by their X-Y coordinates going counter-clockwise around the surface. Only convex surfaces (no interior angle greater than 180 degrees) with 3 or 4 vertices are permitted. Other surfaces should be divided into two or more convex surfaces. The reasons for this are discussed in III.E.4.

IV.F.2 WINDOW AND DOOR SUBSURFACES

The location and size of these features are described in the coordinate system of the base surface (wall, roof, etc.) on which they lie. The size of each window or door is given by its width and height (for example, W=4 / H=6 or equivalently SIZE=4,6). The subsurface is located on the base surface by giving the coordinates of its lower left corner relative to the origin of the base surface (for example X=4 / Y=1.5 or ORG=4,1.5,0). Coordinates are given relative to the base surface coordinate system. Figure F.4 shows the window thus described placed on the wall from figure F.1. The subsurface must lie completely within the base surface. Non-rectangular subsurfaces must be described as equivalent rectangles.

It is common for windows and doors to be set back slightly behind the plane of the base surface. This causes shadowing of the subsurface, especially as the sun's rays become nearly parallel to the surface. The setback is described by the Z coordinate (Z=-.5) of the location of the subsurface. (A "set forward" is not permitted.)

IV.F.3 SHADOWING SUBSURFACES

TARP input (4.15) provides a simple way to describe rectangular shadowing features which are parallel to the major axes of the base surface coordinate system. There are four configurations:

1. An overhang (OHNG) lies parallel to the X-Z plane and can cast shadows downward onto the surface (figure F.5).
2. A left fin (LFIN) lies parallel to the Y-Z plane and is to the left of its shadow (figure F.6).
3. A right fin (RFIN) also lies parallel to the Y-Z plane but lies to the right of its shadow (figure F.7). Section III.E.2 explains why TARP surfaces cast shadows to one side but not the other. It is necessary to use an LFIN and an RFIN to describe a feature which can shade both directions.
4. A projection (PROJ) lies parallel to the X-Y plane in front of the surface which it shadows (figure F.8).

Figures F.5 through F.8 show how the size and position of these shadowing features are described in terms of W, H (or SIZE) and X, Y, Z (or ORG).

A shadowing subsurface will shade the base surface and all its window or door subsurfaces. It will not shade any other base surface.

IV.F.4 ZONE COORDINATE SYSTEM

The surfaces of a zone are located relative to each other in the zone coordinate system. It is a Cartesian coordinate system with a vertical Z-axis and the X and Y axes oriented parallel to major zone features to simplify placement of surfaces. A surface is located in the zone coordinate system by giving the coordinates of the surface origin relative to the zone origin ($X=r$ / $Y=r$ / $Z=r$ or $ORG=r,r,r$ [4.13.6]) and the azimuth ($AZM = r$ [4.13.3]) and tilt ($TILT=r$ [4.13.4]) angles of the surface.

The tilt angle is the angle from the Z-axis to the normal to the surface. A vertical surface has a tilt of 90 degrees. A horizontal roof has a tilt of 0. A floor has a tilt of 180 (the outward normal points down).

Azimuth is the clockwise angle between the Y-axis and the horizontal projection of the outward normal of the surface. For vertical surfaces this is simply the direction the wall faces. Figure F.9 shows the locations, azimuths and tilts of three vertical and three tilted surfaces. For horizontal surfaces the true azimuth angle is undefined, but one must be given to properly locate the surface vertices in the zone coordinate system. This is most easily done by imagining the horizontal surface rotated about an edge until it is vertical to allow identification of origin, width, and height as in figure F.10 for a flat roof and figure F.11 for a floor.

IV.F.5 BUILDING COORDINATE SYSTEM

The building coordinate system is chosen to simplify the placement of zones relative to each other. The X- and Y-axes are usually chosen to lie along the axes of most of the zones. Each zone is located in the building coordinate system by giving the coordinates of the zone origin relative to the building origin ($X=r$ / $Y=r$ / $Z=r$ or $ORG=r,r,r$ [4.1.3]) and the angle from the building Y-axis to the zone Y-axis ($N=n$ [4.1.2]). Figure F.12 shows the location of three zones in a building coordinate system.

Because of the general orientation of the building, the Y-axis may not line up with true north. The angle from true north to the Y-axis of the building coordinate system ($N=r$ [3.1.1]) must be given to allow TARP to compute the true coordinates of the surface vertices.

It is common for buildings to have two or more zones which are geometrically identical except for their location and orientation as shown by the four zone examples in figure F.13. TARP allows two ways to describe zones in terms of others already defined. First is rotation and translation. The description of zone 3 can be produced by duplicating the description of zone 2 and adding a rotation of 180 degrees about the zone origin and shifting the origin to $ORG=24.5,55,0$. This process is illustrated in figure F.14. Use the text editor to duplicate the geometric features of zone 2, and do the rotation and origin translation of the origin in the GEOM (4.1) key. This reduces the number of new lines that must be typed to describe a similar zone.

Zone 4 in figure F.13 is very similar to zone 1, but its geometric description cannot be obtained by any combination of rotations and translations. It is a mirror image of zone 1. Its description must use one of the mirror image commands (MIRX [4.1.5] or MIRY [4.1.6]). Figure F.15 shows how zone 1 is first mirrored in the Y direction (Y coordinates in the zone system are replaced by their negatives) and then translated to a new origin to produce the description of zone 4. Figure F.16 shows that the same results could have been obtained by mirroring in the X direction, rotating 180 degrees, and translating the origin. Mirror imaging works for all surfaces and subsurfaces except those cases where a subsurface is on a non-rectangular base surface which was described with the first vertex not lying on the X-axis (such as the base surface in figure F.3).

IV.F.6 DETACHED SHADOWING SURFACES

The geometry described thus far will allow calculation of shadowing from subsurfaces like fins and overhangs, and from other zone surfaces. In addition the user may wish to describe adjacent buildings or other significant shadow casting features which are not part of a particular zone and which can shade more than one zone or surface. This is done with the "detached shadowing surface" (DSS [3.2]). The description of such a surface involves defining its size and shape (W=r / H=r or SIZE=r,r or VRTS=r,r,r,r,r,r [3.2.4]) as described above for a zone surface and then locating (X=r / Y=r / Z=r or ORG=r,r,r [3.2.3]) and orienting (AZM=r [3.2.1] and TILT=r [3.2.2]) the surface in the building coordinate system. The critical consideration in locating and orienting the surface is that it casts a shadow only into the hemisphere which it faces.

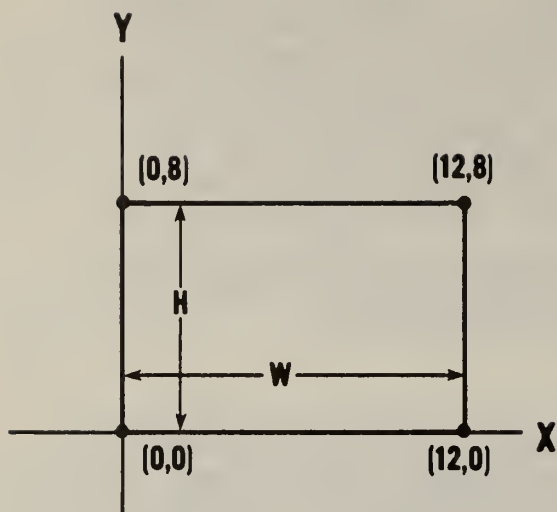


Figure IV.F.1 Rectangle

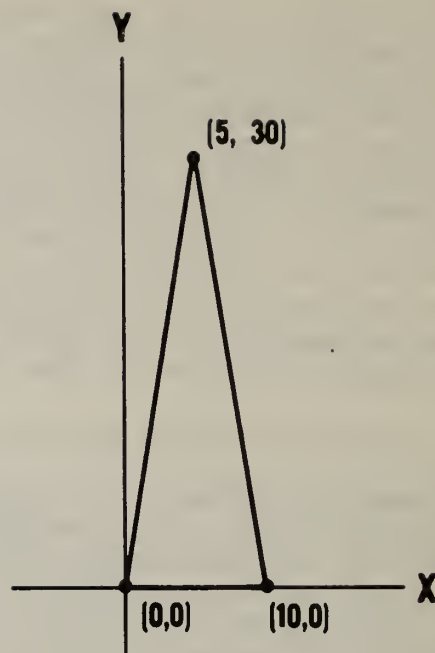


Figure IV.F.2 Triangle

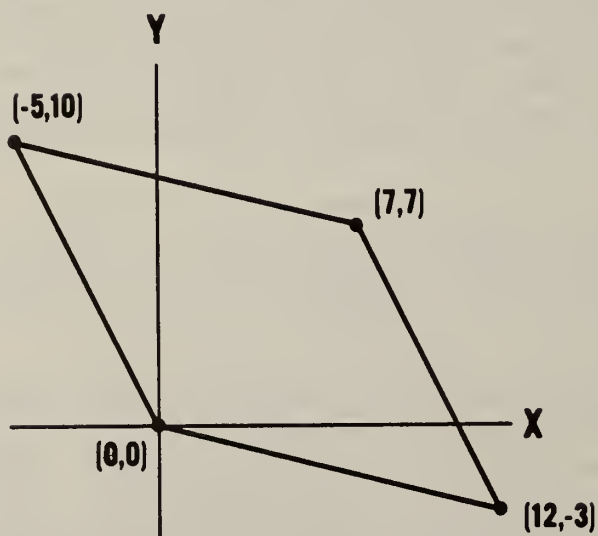


Figure IV.F.3 Quadrilateral

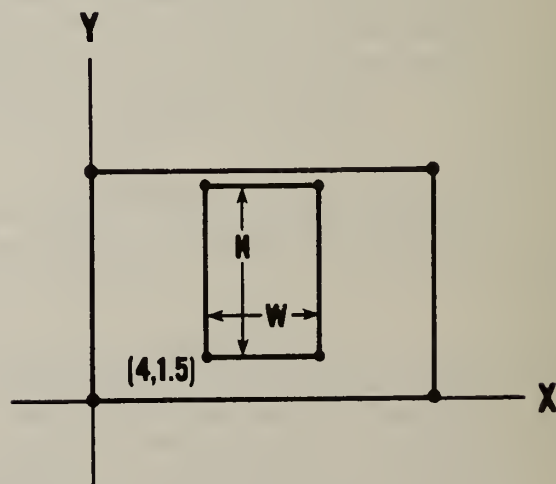


Figure IV.F.4 Window/door subsurface

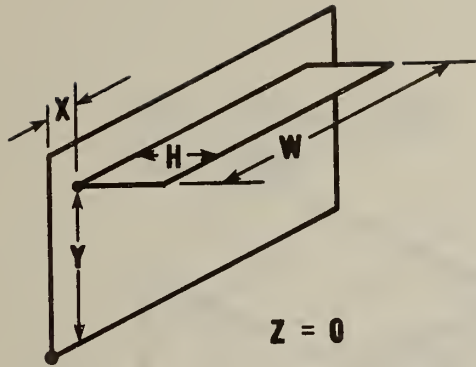


Figure IV.F.5 Overhang

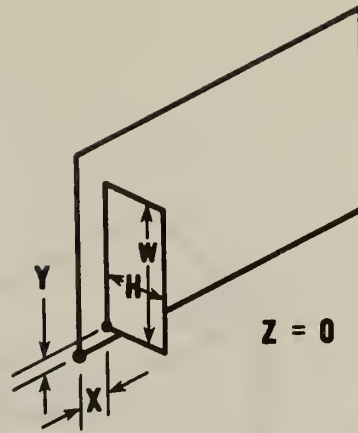


Figure IV.F.6 Left fin

- Subsurface origin
- Base surface origin

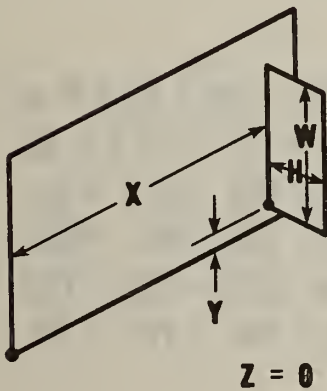


Figure IV.F.7 Right fin

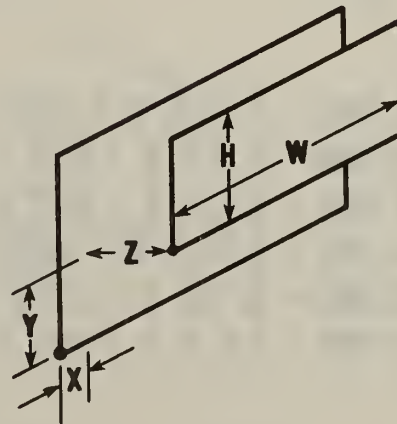
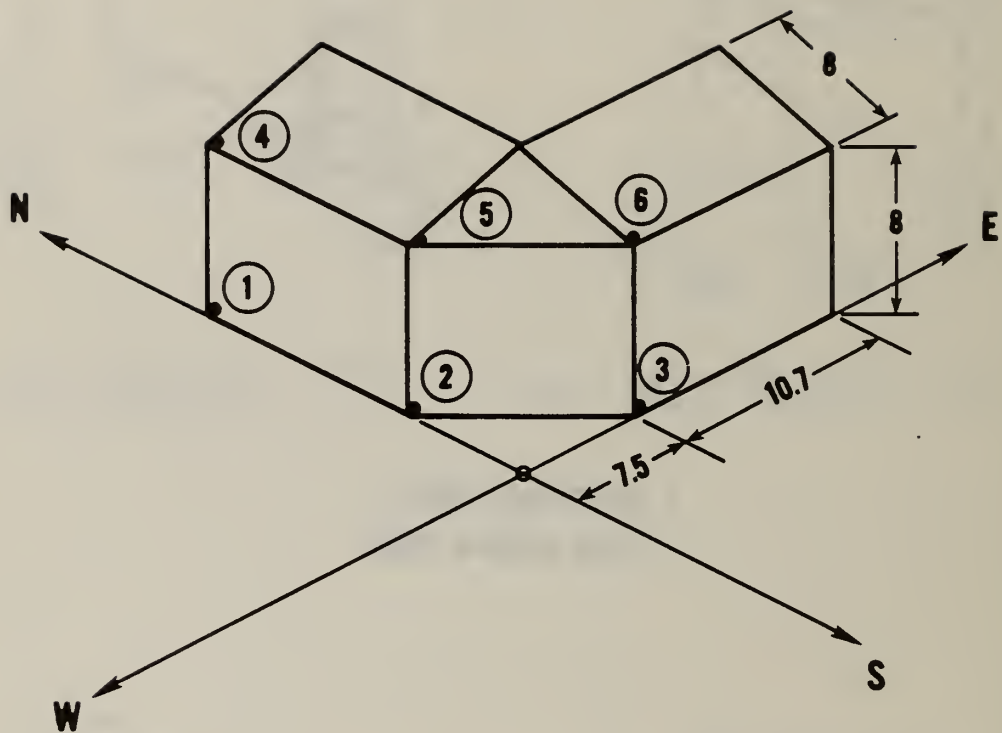


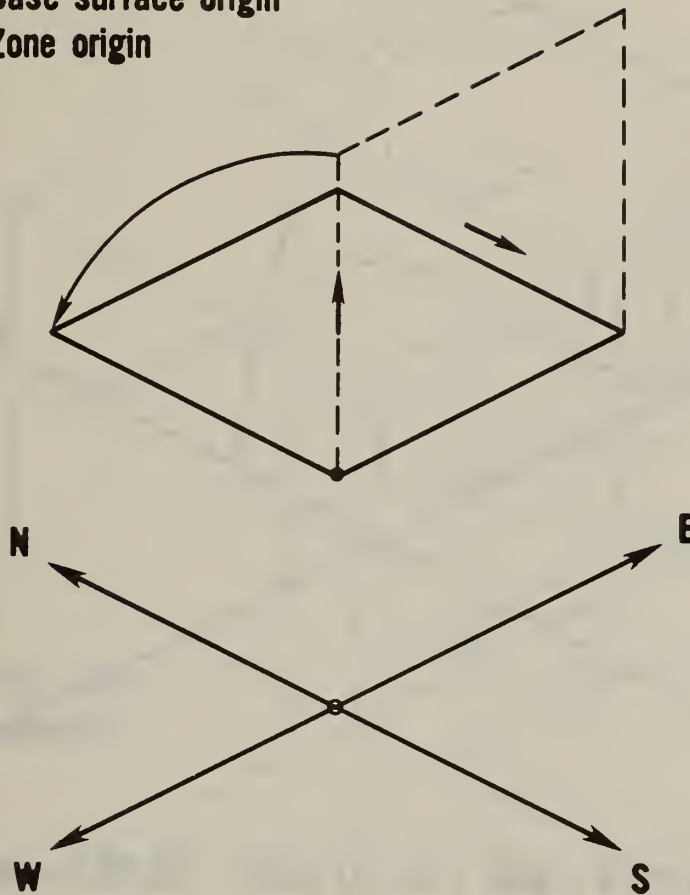
Figure IV.F.8 Projection



- 1: ORG = 0, 18.2, 0 / SIZE = 10.7, 8 / AZM = 270 / TILT = 90
 2: ORG = 0, 7.5, 0 / SIZE = 10.7, 8 / AZM = 225 / TILT = 90
 3: ORG = 7.5, 0, 0 / SIZE = 10.7, 8 / AZM = 180 / TILT = 90
 4: ORG = 0, 18.2, 8 / SIZE = 10.7, 8 / AZM = 270 / TILT = 20
 5: ORG = 0, 7.5, 8 / VRTS = 10.7, 0, 5.3, 4 / AZM = 225 / TILT = 20
 6: ORG = 7.5, 0, 8 / SIZE = 10.7, 8 / AZM = 180 / TILT = 20

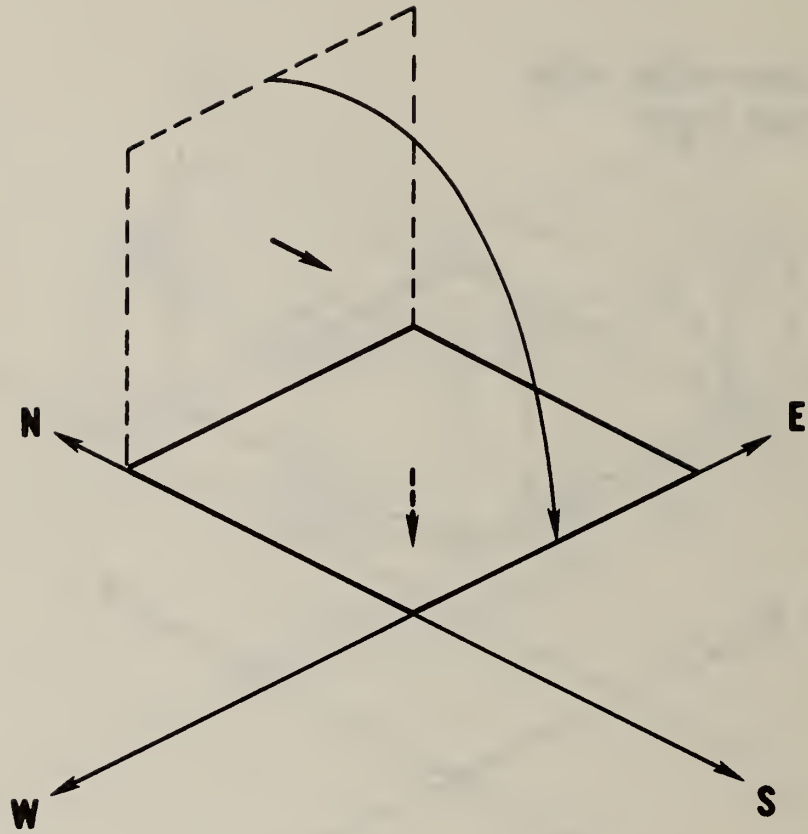
Figure IV.F.9 Zone coordinate system: tilted surfaces

- Base surface origin
- Zone origin



ORG = 0, 0, 8 / SIZE = 12, 12 / AZM = 180 / TILT = 0

Figure IV.F.10 Zone coordinate system: flat roof



ORG = 0, 12, 0 / SIZE = 12, 12/ AZM = 180/TILT = 180

Figure IV.F.11 Zone coordinate system: floor

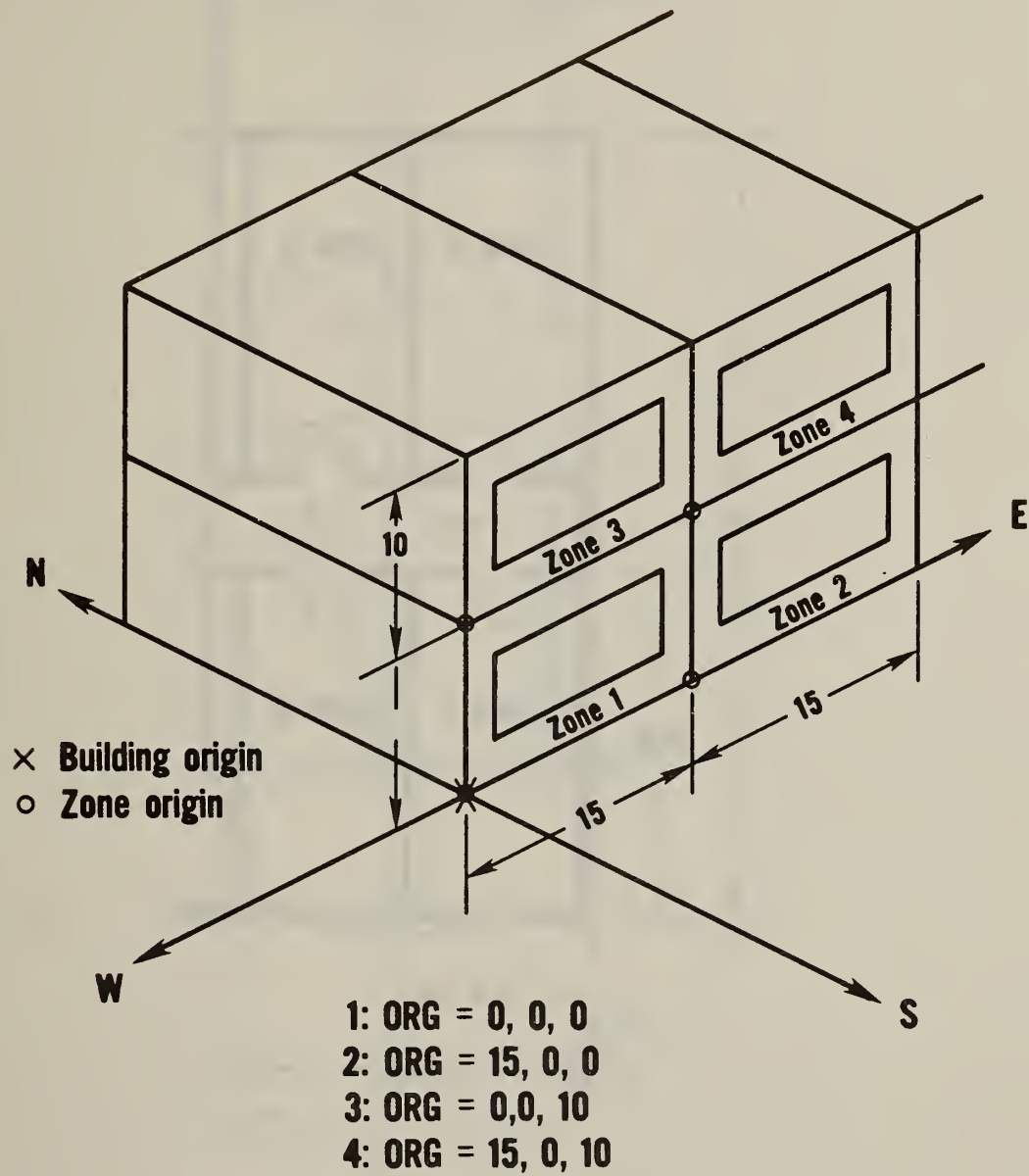


Figure IV.F.12 Building coordinate system: four zones

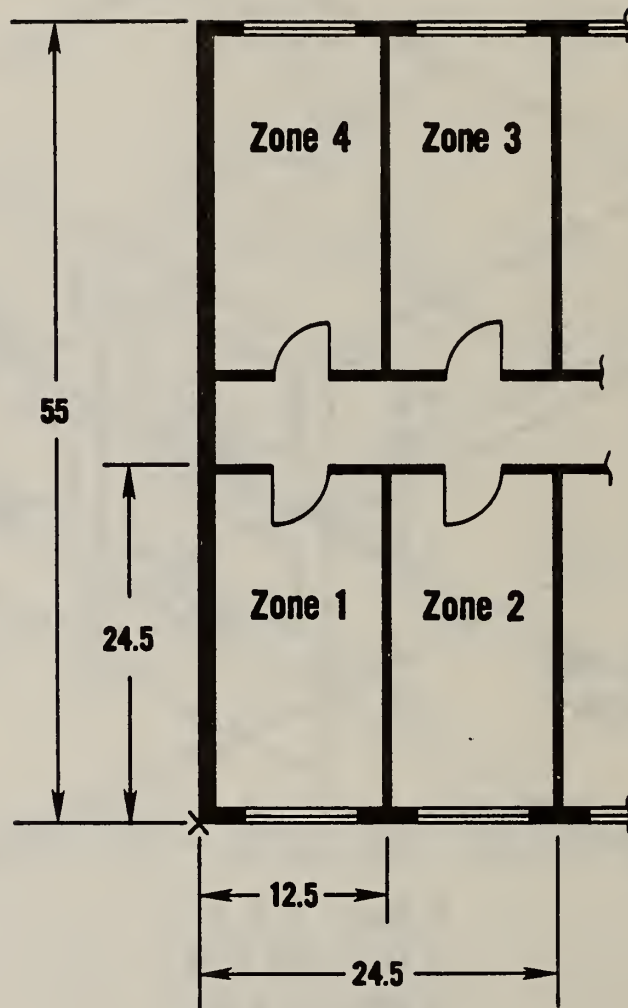
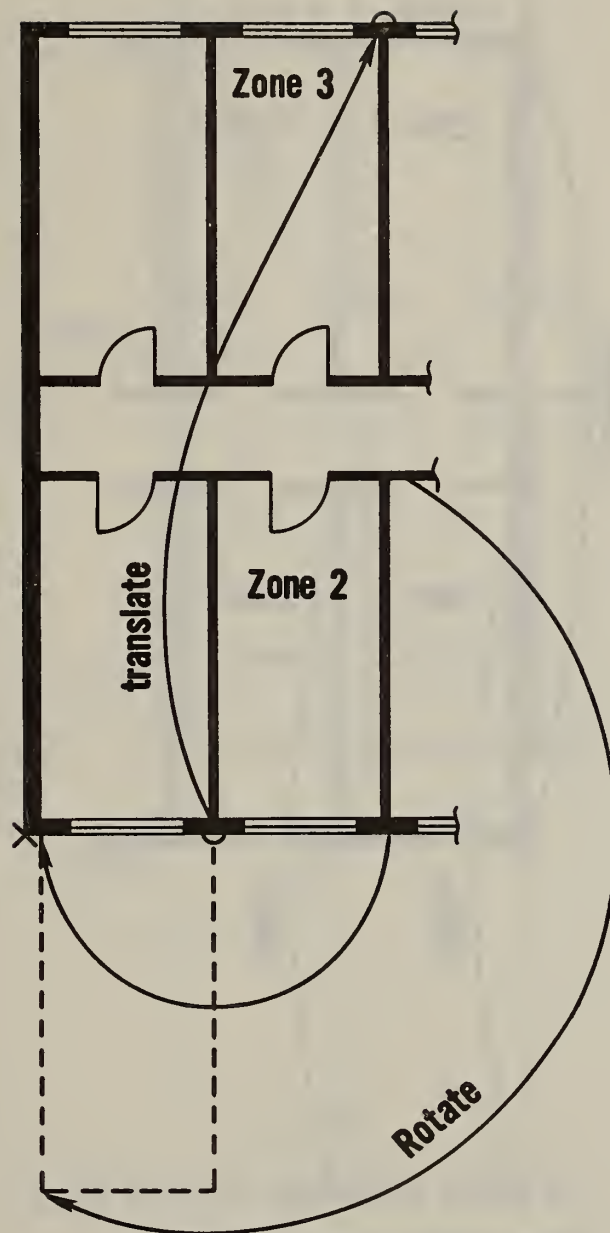
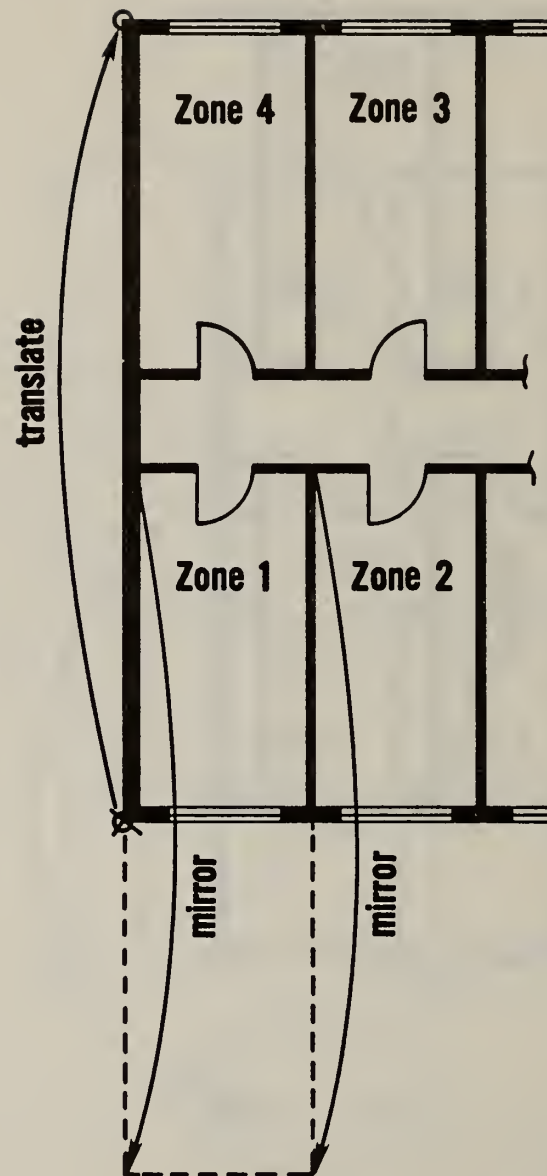


Figure IV.F.13 Portion of building with similar zones



GEOM (N = 180/ ORG = 24.5, 55, 0 / ...

Figure IV.F.14 Zone 3 described by rotation and translation of zone 2



GEOM (MIRY/ORG = 0, 55, 0/ ...

Figure IV.F.15 Zone 4 described by mirror imaging and translation of zone 1

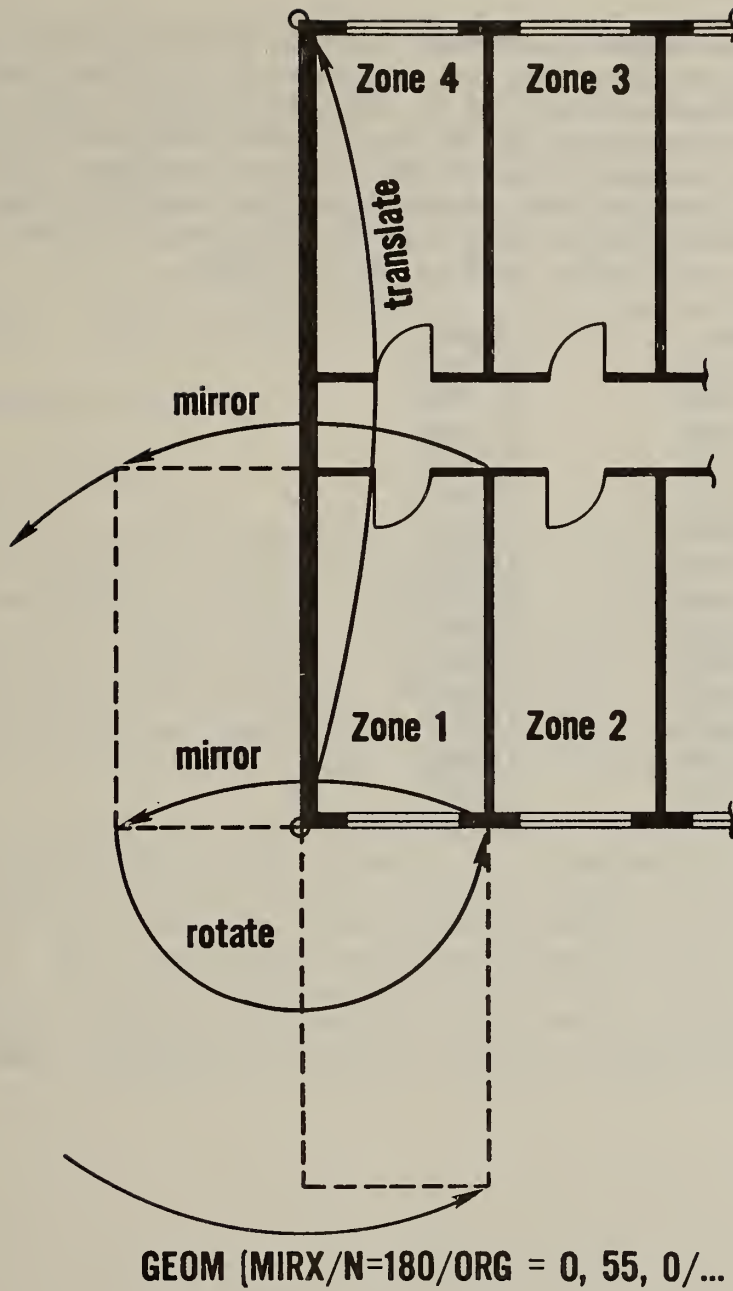


Figure IV.F.16 Zone 4 described by mirror imaging, rotation and translation of zone 1

IV.G TABLES

IV.G.1 SHADOWING DATES

Shadow patterns are normally computed for the 14 time periods listed below. These periods were chosen so that the error in the solar position would be less than 2 degrees on any day in the period. This causes the periods to be shorter around March 21 and Sept 21 when the solar declination angle changes rapidly. Shading features which do not use these dates will increase the number of time periods and therefore the amount of time necessary to calculate shadowing. Most shading features will occur over several time periods, e.g. FROM = 16MAY / THRU = 30SEP.

PERIOD	FROM	THRU
1	1 JAN	31 JAN
2	1 FEB	20 FEB
3	21 FEB	12 MAR
4	13 MAR	31 MAR
5	1 APR	20 APR
6	21 APR	15 MAY
7	16 MAY	31 JUL
8	1 AUG	24 AUG
9	25 AUG	12 SEP
10	13 SEP	30 SEP
11	1 OCT	20 OCT
12	21 OCT	15 NOV
13	16 NOV	15 DEC
14	16 DEC	31 DEC

V. OUTPUT

The Thermal Analysis Research Program produces output in various levels of detail as directed by the user. Output reports generally consist of tables of numbers suitable for printing or display at a terminal. Development of more elegant graphic output has not been pursued because of the TARP emphasis on the fundamental heat transfer algorithms and computational methods. Almost every intermediate result that TARP calculates can be printed. Most of these intermediate results are available through "dumps" which have minimal descriptive information with the numbers and are in metric units -- the internal data representation. Several "reports" are also available. Reports present summary data and can be in either English or metric units. The following sections discuss the various output options.

V.A INPUT REPORTS

V.A.1 Default Reports

The input processor produces an "echo" of the user input. This echo is organized by numbered lines on numbered pages as shown in the report for the sample problem from II.C shown in figure 1 on the following pages. Each page heading includes a page number, title, date, time of day, and central processor execution time. This last number is based on a non-ANSI function and may not be available on all computers. The input lines are numbered primarily to aid in editing the user input file. If user lines are not over about 72 characters long, the output will appear on most terminals without "wrap-around".

The last page of the input processor report tells the unused library elements and the required array dimensions (parameters) for the load calculator. The report of unused library names can help to identify typing errors which cause library elements to not be found when they are referenced later in the input. The report also identifies elements which can be removed from the input deck (possibly by commenting - \$) to use less array space. The array dimensions report tells the minimum parameter sizes (see VI.C for a complete list of parameters) necessary to run the simulation.

```

1 PROJECT [
2   RC(DEM/UID=ENGLISH/UOUT=ENGLISH/
3     DESC='THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN')
4   RPT(RNOS = 9, 21)
5   LOC(DESC='COLUMBIA, MO.'/LATD=38.9/LONG=92.3/TZ=6)
6   GRND(GRT=40,42,48,55,62,67,70,69,63,55,48,42)
7   DDY(DESC='MILD WINTER'/HIGH=50/LOW=30/WB=40/DATE=21FEB/
8     CLR=1./MON/WS=1320/DIR=315)
9   ]
10 LIBRARY [
11   DS(NAME=NONE/DESC='ZERO ALL HOURS'/FFC=24*0)
12   DS(NAME=FULL/DESC='ONE ALL HOURS'/FFC=24*1)
13   DS(NAME=ON/DESC='NORTH OCCUPANCY'/
14     FFC=6*1,.5,.16,8*0,4*.16,2*.33,.67,1)
15   DS(NAME=OC/DESC='CENTER OCCUPANCY'/
16     FFC=16*0,3*.17,.67,.5,.67,.17,0)
17   DS(NAME=OS/DESC='SOUTH OCCUPANCY'/
18     FFC=6*0,.5,.5,8*0,2*.33,.67,2*.16,3*0)
19   WS(NAME=OCN/DESC='NORTH OCCUPANCY'/WD=ON)
20   WS(NAME=OCC/DESC='CENTER OCCUPANCY'/WD=OC)
21   WS(NAME=OCS/DESC='SOUTH OCCUPANCY'/WD=OS)
22   DS(NAME=LN/DESC='NORTH LIGHTING'/
23     FFC=6*0,.7,.7,8*0,2*.33,4*.7,.4,0)
24   DS(NAME=LC/DESC='CENTER LIGHTING'/
25     FFC=16*0,.5,5*.7,.3,0)
26   DS(NAME=LS/DESC='SOUTH LIGHTING'/
27     FFC=6*0,.7,.7,8*0,5*.7,3*0)
28   WS(NAME=LITN/DESC='NORTH LIGHTING'/WD=LN)
29   WS(NAME=LITC/DESC='CENTER LIGHTING'/WD=LC)
30   WS(NAME=LITS/DESC='SOUTH LIGHTING'/WD=LS)
31   DS(NAME=EN/DESC='NORTH EQUIPMENT'/
32     FFC=20*0,3*1,0)
33   DS(NAME=EC/DESC='CENTER EQUIPMENT'/
34     FFC=16*0,4*1,4*0)
35   DS(NAME=ES/DESC='SOUTH EQUIPMENT'/
36     FFC=6*.3,2*1,8*.3,2*1,3*.7,3*.3)
37   WS(NAME=EQFN/DESC='NORTH EQUIPMENT'/WD=EN)
38   WS(NAME=EQPC/DESC='CENTER EQUIPMENT'/WD=EC)
39   WS(NAME=EQPS/DESC='SOUTH EQUIPMENT'/WD=ES)
40   WS(NAME=CONST/DESC='CONSTANT 100%/ALL=FULL)
41   MATL(NAME=GYP/DESC='GYPSUM WALLBOARD'/K=.42/D=45./CP=.3)
42   MATL(NAME=WD-S/DESC='SOFTWOOD'/K=.0675/D=32./CP=.33)
43   MATL(NAME=SHTH/DESC='INTERMEDIATE DENSITY BUILDING BOARD SHEATHING'/
44     K=.034/D=22./CP=.31)
45   MATL(NAME=C-HW/DESC='HEAVY CONCRETE'/K=1.0/CP=.2/D=140.)
46   MATL(NAME=R1/DESC='AIRSPACE RESISTANCE'/R=.91/AIR)
47   MATL(NAME=R5/DESC='R5 POLYSTYRENE'/R=5.)
48   MATL(NAME=R19/DESC='R19 INSULATION'/R=19.)
49   MATL(NAME=R30/DESC='R30 INSULATION'/R=30.)
50   MATL(NAME=SPDS/DESC='STANDARD GLASS'/GLASS/R=.0236/TRNS=.86)
51   MATL(NAME=ASH/DESC='ASPHALT SHINGLES'/K=18.16/D=70/CP=.3)
52   MATL(NAME=DIRT/K=.1/D=65./A=.70)

```

Figure V.1 Sample default output


```

53  MATL(NAME=AL/DESC='ALUMINUM SIDING'/K=128/D=171./CP=.2)
54  MATL(NAME=CPT/DESC='CARPET & PAD'/R=2.08)
55  CONS(NAME=WL-I/DESC='EXTERIOR WALL - INSULATION AREA'/
56      MATL=.0052,AL, .0417,SHTH, 0,R19, .0521,GYP)
57  CONS(NAME=WL-S/DESC='EXTERIOR WALL- STUD AREA'/
58      MATL=.0052,AL, .0417,SHTH, .292,WD-S, .0521,GYP)
59  CONS(NAME=PTN-A/DESC='PARTITION - AIR SPACE AREA'/
60      MATL=.0521,GYP, 0,B1, .0521,GYP)
61  CONS(NAME=PTN-S/DESC='PARTITION - STUD AREA'/
62      MATL=.0521,GYP, .292,WD-S, .0521,GYP)
63  CONS(NAME=WDW2/DESC='2 PANE WINDOW'/
64      MATL=0,SPDS, 0,B1, 0,SPDS)
65  CONS(NAME=FRAME/DESC='WINDOW FRAME'/MATL=0.1354,WD-S)
66  CONS(NAME=RF-T/DESC='CEILING/ROOF - TRUSS AREA'/
67      MATL=.0104,ASH, .0417,WD-S, .625,WD-S, .0417,GYP)
68  CONS(NAME=RF-I/DESC='CEILING/ROOF - INSULATION AREA'/
69      MATL=.0104,ASH, .0417,WD-S, 0,R30, .0417,GYP)
70  CONS(NAME=PTN-M/DESC='MASSIVE PARTITION'/MATL=.667,C-HW)
71  CONS(NAME=SLAB-C/DESC='SLAB WITH CARPET'/
72      MATL=.5,DIRT, 0,R5, .333,C-HW, 0,CPT)
73  CONS(NAME=SLAB-T/DESC='SLAB WITH TILE'/
74      MATL=.5,DIRT, 0,R5, .333,C-HW)
75  CPFL(NAME=P1/DESC='HEATING SETBACK'/CAP=1,0/TMP=60,62)
76  CPFL(NAME=P2/DESC='STANDARD HEATING'/CAP=1,0/TMP=68,70)
77  CDS(NAME=HN/DESC='NORTH HEATING'/CPFL=6*P1,2*P2,8*P1,6*P2,2*P1)
78  CDS(NAME=HC/DESC='CENTER HEATING'/CPFL=16*P1,6*P2,2*P1)
79  CDS(NAME=HS/DESC='SOUTH HEATING'/CPFL=6*P1,2*P2,8*P1,5*P2,3*P1)
80  CWS(NAME=HEATN/DESC='NORTH HEATING'/WD=HN)
81  CWS(NAME=HEATC/DESC='CENTER HEATING'/WD=HC)
82  CWS(NAME=HEATS/DESC='SOUTH HEATING'/WD=HS)
83  ]
84  BUILDING [
85      SIM(SLIS=3/HTB=0/FLOW/CNUG=.1,.01,.34,12)
86      DSS(AZM=180./TILT=153.4/ORG=0,12,16/SIZE=44,2)
87      DSS(AZM=180./TILT=206.6/ORG=0,0,8/SIZE=44,2)
88      DSS(AZM=0./TILT=116.6/ORG=0,36,8/SIZE=44,2)
89  ]
90  ZONE [
91      GEOM(NAME=NORTH)
92      CTRL(CWS=HEATN/HEAT=12)
93      PEO(WS=OCCN/CAP=3)
94      LIT(WS=LITN/CAP=1.4)
95      EQP(WS=EQPN/CAP=1.0)
96      MASS(CONS=PTN-A/AREA=480)
97      SRF(EX/OP/BS/CONS=WL-I/AZM=0/ORG=44,36,0/SIZE=41,8)
98      SRF(EX/TR/SS/CONS=WDW2/ORG=12,5,-.25/SIZE=20,2)
99      AFS(AREA=0.2/EXP=.65)
100     SRF(EX/OP/BS/CONS=WL-S/AZM=0/ORG=3,36,0/SIZE=3,8)
101     SRF(EX/OP/BS/CONS=RF-T/AZM=0/ORG=44,36,8/SIZE=41,8.95/TILT=26.6)
102     AFS(AREA=0.1/EXP=.65)
103     SRF(EX/OP/BS/CONS=RF-I/AZM=0/ORG=3,36,8/SIZE=3,8.95/TILT=26.6)
104     SRF(IN/OP/BS/CONS=PTN-M/AZM=180/ORG=0,24,0/SIZE=44,12/ZONE=CENTER)

```

Figure V.1 (continued)

```

105     AFS(AREA=0.5/EXP=.50)
106     SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,36,0/VRTS=12,0, 12,12, 0,8)
107     SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,24,0/VRTS=12,0, 12,8, 0,12)
108     SRF(EX/OP/BS/CONS=SLAB-C/AZM=180/ORG=0,36,0/SIZE=44,12/TILT=180)
109     OSC(TGP=1)
110 ]
111 ZONE C
112     GEOM(NAME=CENTER)
113     CTRL(CWS=HEATC/HEAT=12)
114     FEO(WS=OCCC/CAP=3)
115     LIT(WS=LITC/CAP=1.4)
116     EQP(WS=EQPC/CAP=1.0)
117     MASS(CONS=PTN-A/AREA=480)
118     SRF(EX/OP/BS/CONS=FRAME/AZM=180/ORG=0,12,12/SIZE=44,3)
119     SRF(EX/TR/SS/CONS=WDW2/ORG=2,0,-.25/SIZE=40,3)
120     AFS(AREA=0.25/EXP=.65)
121     SRF(EX/OP/BS/CONS=RF-T/AZM=0/ORG=44,24,12/SIZE=41,8.95/TILT=26.6)
122     AFS(AREA=0.1/EXP=.65)
123     SRF(EX/OP/BS/CONS=RF-I/AZM=0/ORG=3,24,12/SIZE=3,8.95/TILT=26.6)
124     SRF(IN/OP/BS/CONS=PTN-A/AZM=180/ORG=3,12,0/SIZE=41,12/ZONE=SOUTH)
125     AFS(AREA=0.5/EXP=.50)
126     SRF(IN/OP/BS/CONS=PTN-S/AZM=180/ORG=0,12,0/SIZE=3,12/ZONE=SOUTH)
127     SRF(IN/OP/BS/CONS=PTN-M/AZM=0/ORG=44,24,0/SIZE=44,12/ZONE=NORTH)
128     AFS(AREA=0.5/EXP=.50)
129     SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,24,0/VRTS=12,0, 12,16, 0,12)
130     SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,12,0/VRTS=12,0, 12,12, 0,16)
131     SRF(EX/OP/BS/CONS=SLAB-C/AZM=180/ORG=0,24,0/SIZE=44,12/TILT=180)
132     OSC(TGP=1)
133 ]
134 ZONE C
135     GEOM(NAME=SOUTH)
136     CTRL(CWS=HEATS/HEAT=12)
137     FEO(WS=OCCS/CAP=3)
138     LIT(WS=LITS/CAP=1.4)
139     EQP(WS=EQFS/CAP=9.4/LOST=.4)
140     MASS(CONS=PTN-A/AREA=480)
141     SRF(EX/OP/BS/CONS=WL-I/AZM=180/ORG=0,0,0/SIZE=41,8)
142     SRF(EX/TR/SS/CONS=WDW2/ORG=12,3,-.25/SIZE=20,4)
143     AFS(AREA=0.2/EXP=.65)
144     SRF(EX/OP/BS/CONS=WL-S/AZM=180/ORG=41,0,0/SIZE=3,8)
145     SRF(EX/OP/BS/CONS=RF-T/AZM=180/ORG=0,0,8/SIZE=41,8.95/TILT=26.6)
146     AFS(AREA=0.1/EXP=.65)
147     SRF(EX/OP/BS/CONS=RF-I/AZM=180/ORG=41,0,8/SIZE=3,8.95/TILT=26.6)
148     SRF(IN/OP/BS/CONS=PTN-A/AZM=0/ORG=44,12,0/SIZE=41,12/ZONE=CENTER)
149     AFS(AREA=0.5/EXP=.50)
150     SRF(IN/OP/BS/CONS=PTN-S/AZM=0/ORG=3,12,0/SIZE=3,12/ZONE=CENTER)
151     SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,12,0/VRTS=12,0, 12,8, 0,12)
152     SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,0,0/VRTS=12,0, 12,12, 0,8)
153     SRF(EX/OP/BS/CONS=SLAB-T/AZM=180/ORG=0,12,0/SIZE=44,12/TILT=180)
154     OSC(TGP=1)
155 ]

```

Figure V.1 (continued)

UNUSED LIBRARY NAMES (IF ANY):
DAY-SCHEDULE: NONE
WEEK-SCHEDULE: CONST

MRLP MINIMUM ARRAY DIMENSIONS:

ZON:	3
SRF:	32
HTS:	32
AFS:	10
CGS:	12
GTP:	1
TFH:	283
CTF:	140
SSC:	3
DSH:	11
WSH:	10
CON:	11
PFL:	2
CDS:	3
CWS:	3

Figure V.1 (concluded)

V.A.2 RUN CONTROL MODIFICATIONS

The run control statement (1.1) includes four optional modifications of the output.

V.A.2.1 DEM and error messages.

TARP does extensive input checking. Incorrect or questionable input is reported to the user by error messages which begin with two stars and a severity descriptor. Figure 2 shows how error messages appear in the output. NAME has been misspelled as NAEM in line 15 of the input. This is immediately reported. Since DEM (1.1.3) was specified in the run control statement, a list of valid key words is also printed. Errors that might occur due to bad punctuation, causing the input processor to believe it is in a different input section, can be quickly spotted from the SECTION: and KEY: entries. At the end of the day-schedule description (line 16) it is noted that the user did not give this schedule a name (since the required NAME subkey was never recognized). The error in line 15 propagates through the program causing some other errors to be noted. At line 20, the week-schedule is not created because the day schedule named OC could not be found. The final error message at the end of the output indicates that a loads input file (the SINPFL) was not created. All input which produces SEVERE errors must be corrected before the SINPFL is created.

1DEM AND ERROR MESSAGES

```
15  DS(NAEM=OC/DESC='CENTER OCCUPANCY'/
** SEVERE  INVALID SUBKEY: NAEM
      SECTION: LIBRARY      KEY: DS      VALID SUBKEYS ARE:
      NAME      DESC      FFC
16  FFC=16*0,3*.17,.67,.5,.67,.17,0)
** SEVERE  LIBRARY ELEMENT MUST HAVE NAME
17  DS(NAME=OS/DESC='SOUTH OCCUPANCY'/
18  FFC=6*0,.5,.5,8*0,2*.33,.67,2*.16,3*0)
19  WS(NAME=OCCN/DESC='NORTH OCCUPANCY'/WD=ON)
20  WS(NAME=OCCC/DESC='CENTER OCCUPANCY'/WD=OC)
** SEVERE  OC      NOT IN LIBRARY
** SEVERE  WEEKDAY-SCHEDULE NOT DEFINED
.
.
.
** FATAL  INPUT FILE NOT CREATED BECAUSE OF 'SEVERE' ERRORS
```

Figure V.2 Sample error messages

V.A.2.2 Double spacing

The 2SPC command (1.1.4) causes a blank line to be printed before every input line echo as shown in figure 3. Note that double spacing does not begin until the command has been recognized, so there is no skip between lines 1 and 2.

```
PAGE 1 NBS THERMAL ANALYSIS RESEARCH PROGRAM 82/05/07. 07.07.18. .707

1 PROJECT [
2   RC(DEM/2SPC/UIN=ENGLISH/UOUT=ENGLISH/

3     DESC='THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN')

4   RPT(RNOS = 9)

5   LOC(DESC='COLUMBIA, MO.'/LATD=38.9/LONG=92.3/TZ=6)

6   GRND(GRT=40,42,48,55,62,67,70,69,63,55,48,42)

7   DDY(DESC='MILD WINTER'/HIGH=50/LOW=30/WB=40/DATE=21FEB/

8     CLR=1./MON/WS=1320/DIR=315)

9   ]

10 LIBRARY [

11   DS(NAME=NONE/DESC='ZERO ALL HOURS'/FFC=24*0)

12   DS(NAME=FULL/DESC='ONE ALL HOURS'/FFC=24*1)
```

Figure V.3 Double spacing

V.A.2.3 Cross referencing

The XREF command (1.1.5) allows the user to match the data in the reports and, especially, the dumps to his input. In general, the input is read and organized into various arrays. The XREF reports the array locations. In figure 4, line 87 describes a detached shadowing surface (3.2). Information about this surface will be stored as element 2 in arrays having a MAXSRF parameter dimension. The next DSS (line 88) is stored as element 3 in those arrays. Zone controls and scheduled loads (lines 92-95) are stored in arrays with MAXCGS dimensions. The MASS is the first heat transfer surface, so its data goes into the MAXHTS dimensioned arrays at location 1. The surface description (line 97) has two cross references because both geometric data (in MAXSRF dimensioned arrays) and heat transfer data (in MAXHTS arrays) must be stored. The zone number appears after the zone description is completed (line 110).

```

      .
      .
      .
87   DSS(AZM=180./TILT=206.6/ORG=0,0,8/SIZE=44,2)
      SRF = 2
88   DSS(AZM=0./TILT=116.6/ORG=0,36,8/SIZE=44,2)
      SRF = 3
89   ]
90   ZONE [
91     GEOM(NAME=NORTH)
92     CTRL(CWS=HEATN/HEAT=12)
      CGS = 1
93     PED(WS=OCCN/CAP=3)
      CGS = 2
94     LIT(WS=LITN/CAP=1.4)
      CGS = 3
95     EQP(WS=EQPN/CAP=1.0)
      CGS = 4
96     MASS(CONS=PTN-A/AREA=480)
      HTS = 1
97     SRF(EX/OF/BS/CONS=WL-I/AZM=0/ORG=44,36,0/SIZE=41,8)
      SRF = 4
      HTS = 2
98     SRF(EX/TR/SS/CONS=WDW2/ORG=12,5,-.25/SIZE=20,2)
      SRF = 5
      HTS = 3
99     AFS(AREA=0.2/EXP=.65)
      AFS = 1
      .
      .
      .
107    SRF(IN/OF/BS/CONS=PTN-M/AZM=90/ORG=44,24,0/VRTS=12,0, 12,8, 0,12)
      SRF = 11
      HTS = 9
108    SRF(EX/OF/BS/CONS=SLAB-C/AZM=180/ORG=0,36,0/SIZE=44,12/TILT=180)
      SRF = 12
      HTS = 10
109    OSC(TGP=1)
      SSC = 1
110  ]
      ZON = 1
111  ZONE [
112    GEOM(NAME=CENTER)
113    CTRL(CWS=HEATC/HEAT=12)
      CGS = 5
114    PED(WS=OCCC/CAP=3)
      CGS = 6

```

Figure V.4 Cross references

V.A.2.4 Metric units

TARP processes input and writes reports in English units by default. The user can request that the input or output or both be in metric units (1.1.7). Two samples of metric reports are shown in figure 5. The first is the final loads summary described in V.B.1. Second is a wall and conduction transfer function report described in V.A.4.4.

BUILDING LOADS FOR

THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN

COLUMBIA, MO.

MILD WINTER

ZONE	TOTAL HEATING (KWH)	TOTAL COOLING (KWH)	PEAK HEATING (KW)	PEAK COOLING (KW)	MAX TEMP (C)	MIN TEMP (C)	HX	HT	V	CL	CX
NORTH	14.94	0.00	2.977	0.000	20.71	16.61	0	10	0	0	0
CENTER	.33	0.00	.330	0.000	22.84	17.83	0	2	0	0	0
SOUTH	.09	0.00	.090	0.000	25.48	19.98	0	1	0	0	0
TOTAL:	1.534E+01 0.		3.067	0.000	25.48	16.61					

MAX HEATING OCCURS AT HOUR 7 ON 21FEB
 MAX TEMP OCCURS AT HOUR 18 ON 21FEB
 MIN TEMP OCCURS AT HOUR 6 ON 21FEB

PTN-S : PARTITION - STUD AREA
 4:

DESCRIPTION OF CONSTRUCTION

LAYER	THICKNESS METERS	CONDUCTIVITY W/(M*K)	DENSITY KG/M**3	SPECIFIC HEAT KJ/(KG*K)	RESISTANCE M**2*K/W
GYP	.0159	.726	720.831	1.255	0.000
WD-S	.0890	.117	512.591	1.381	0.000
GYP	.0159	.726	720.831	1.255	0.000

5 CONDUCTION TRANSFER FUNCTIONS OF ORDER 2

TIME	INTERNAL	CROSS	EXTERNAL	FLUX
1	8.68390584	.01854220	8.68390584	.58886750
2	-11.49423688	.30212722	-11.49423688	-.03735637
3	3.53278776	.22263065	3.53278776	
4	-.16599941	.01302198	-.16599941	
5	-.00006837	.00006688	-.00006837	

THERMAL CONDUCTANCE = 1.241 W/(M**2*K)
 OUTER THERMAL ABSORPTANCE = .90
 INNER THERMAL ABSORPTANCE = .90
 OUTER SOLAR ABSORPTANCE = .75
 INNER SOLAR ABSORPTANCE = .75
 OUTER SURFACE ROUGHNESS =ROUGH

Figure V.5 Two reports using metric units

V.A.3 NUMBERED REPORTS

Seven data dumps can be requested by specifying report numbers (1.2.1).

V.A.3.1 RNOS = 1; dump PROJECT and LIBRARY data

This provides summaries at the end of the PROJECT and LIBRARY sections. The DUMP OF PROJECT CONTROL DATA shown below lists the values associated with different variables which can be set in the PROJECT section. Refer to VI.C for a description of the individual variables.

DUMP OF PROJECT CONTROL DATA

```
COMMON /TITLES/:
PTITLE = THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN
LTITLE = COLUMBIA, MO.
ETITLE = MILD WINTER

COMMON /RUNCTL/:
EMUI   =          2
SYNTAX =          F
CALCS  =          T
DEM    =          T
OLDW   =          F

COMMON /EFLHDR/:
LATD   =      38.900
LONG   =      92.300
TZNR   =      6.000
ALTD   =      0.000
TERRAIN =      3
SINL   =      .628
COSL   =      .778
MERID  =      2.300
TGRND  =  4.4  5.6  8.9 12.8 16.7 19.4 21.1 20.6 17.2 12.8  8.9  5.6
TMKUP  = 12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8
NRENUVS =      1
NRDAYS  =      1
WSTATN =      0

COMMON /REPORT/:
EMUD   =      2
RFLAGS =  T    T    T    T    T    T    T    F    F    F
          F    F    F    F    F    F    F    F    F    F
          F    F    F    F    F    F    F    F    F    F
```

Figure V.6 Dump of project control data

The DUMP OF LIBRARY CONTROL DATA shown below gives the number and names of all library entries. First, summary data is given for each of the seven libraries. This data is taken from common block LIBCTL. It begins with the day-schedule (DS) by giving the 0 location (DS0), the number of schedules defined (NDS), and the maximum number of schedules permitted (MXDS). This last number can be set by the user (2.1.2). Similar data is presented for the other six libraries. Next comes a list of all library element names (LNAMES) presented in eight names per row in sequence. The list of numbers can be used to determine to which library the names belong. For example, the first 16 names are day-schedules. DS names occupy the first two rows including the five undefined (blank) names in the second row. Week-schedules (WS) names occupy the next two rows with ten names defined and six left undefined, etc.

DUMP OF LIBRARY CONTROL DATA

LIBRARY NAME =

DS =	0	11	16
WS =	16	10	16
MATL =	32	13	16
CONS =	48	11	16
CPFL =	64	2	16
CDS =	80	3	16
CWS =	96	3	16

ELEMENT NAMES:

NONE	FULL	ON	OC	OS	LN	LC	LS
EN	EC	ES					
OCCN	OCCC	OCCS	LITN	LITC	LITS	EQPN	EQFC
EQFS	CONST						
GYP	WI-S	SHTH	C-HW	B1	R5	R19	R30
SPDS	ASH	DIRT	AL	CPT			
WL-I	WL-S	PTN-A	PTN-S	WDW2	FRAME	RF-T	RF-I
PTN-M	SLAB-C	SLAB-T					
P1	F2						
HN	HC	HS					
HEATN	HEATC	HEATS					

Figure V.7 Dump of library control data

V.A.3.2 RNOS = 2; dump of DDY and WTAP data

This is a dump of all weather data for every day described in the DDY (1.6) and WTAP (1.5) keys. It is a dump of data in the EVDAT common block. The data names are summarized as follows:

NAME	VARIABLE	DESCRIPTION
YEAR	YEAR	year
MO	MONTH	month number
DY	DYOFM	day of month
DW	DAYOFW	day of week number
HOL	HOLIND	holiday and special days indicator
DST	DSTIND	daylight saving time indicator
SSDECL	SSDECL	sine of the solar declination angle
CSDECL	CSDECL	cosine of the solar declination angle
EQTIME	EQTIME	equation of time (h)
TD	ODB	dry bulb temperature (C)
TW	OWB	wet bulb temperature (C)
BP	OBP	barometric pressure (Pa)
H	OHR	humidity ratio
WS	SPD	wind speed (m/s)
WD	DIR	wind direction (deg)
TS	SKY	sky radiative temperature (C)
QB	SRADBM	direct normal (beam) solar flux (W/m**2)
QD	SRADDF	sky brightness (W/m**2)
QR	SRADGR	ground brightness (W/m**2)
RN	RAIN	rain indicator
SN	SNOW	snow indicator

```

7 DDY(DESC='MILD WINTER'/HIGH=50/LOW=30/WB=40/DATE=21FEB/
8 CLR=1./MON/WS=1320/DIR=315)

```

```

YEAR MO DY DW HOL DST SSDECL CSDECL EQTIME
1958 2 21 2 0 0 -.184 .983 -.229

```

TD	TW	BP	H	WS	WD	TS	QB	QD	QR	RN	SN
.33	-.87	100000.	.0031	6.7	315.	-16.16	0.0	0.0	0.0	0	0
-.22	-1.19	100000.	.0031	6.7	315.	-16.69	0.0	0.0	0.0	0	0
-.67	-1.45	100000.	.0031	6.7	315.	-17.10	0.0	0.0	0.0	0	0
-1.00	-1.64	100000.	.0031	6.7	315.	-17.42	0.0	0.0	0.0	0	0
-1.11	-1.71	100000.	.0031	6.7	315.	-17.52	0.0	0.0	0.0	0	0
-.89	-1.58	100000.	.0031	6.7	315.	-17.31	0.0	0.0	0.0	0	0
-.33	-1.25	100000.	.0031	6.7	315.	-16.79	0.0	0.0	0.0	0	0
.67	-.67	100000.	.0031	6.7	315.	-15.85	307.4	18.6	10.2	0	0
2.11	.09	100000.	.0031	6.7	315.	-14.49	734.5	44.5	51.1	0	0
3.78	1.05	100000.	.0031	6.7	315.	-12.93	875.8	53.1	88.0	0	0
5.67	2.12	100000.	.0031	6.7	315.	-11.15	937.7	56.8	116.1	0	0
7.44	3.09	100000.	.0031	6.7	315.	-9.48	965.4	58.5	133.2	0	0
8.78	3.80	100000.	.0031	6.7	315.	-8.23	972.2	58.9	138.0	0	0
9.67	4.27	100000.	.0031	6.7	315.	-7.39	961.0	58.2	130.2	0	0
10.00	4.44	100000.	.0031	6.7	315.	-7.08	927.0	56.2	110.4	0	0
9.67	4.27	100000.	.0031	6.7	315.	-7.39	852.7	51.7	80.0	0	0
8.89	3.86	100000.	.0031	6.7	315.	-8.12	675.5	40.9	41.5	0	0
7.67	3.21	100000.	.0031	6.7	315.	-9.27	107.0	6.5	2.6	0	0
6.22	2.43	100000.	.0031	6.7	315.	-10.63	0.0	0.0	0.0	0	0
4.78	1.62	100000.	.0031	6.7	315.	-11.99	0.0	0.0	0.0	0	0
3.56	.93	100000.	.0031	6.7	315.	-13.14	0.0	0.0	0.0	0	0
2.44	.28	100000.	.0031	6.7	315.	-14.18	0.0	0.0	0.0	0	0
1.56	-.17	100000.	.0031	6.7	315.	-15.02	0.0	0.0	0.0	0	0
.89	-.55	100000.	.0031	6.7	315.	-15.64	0.0	0.0	0.0	0	0

Figure V.8 Dump of weather data

V.A.3.3 RNOS = 3; dump of conduction transfer function calculations

Details of the CTF calculations are presented beginning with a list of the layers and their thermal properties (L = thickness, K = conductivity, CP = specific heat, D = density, R = thermal resistance value). SUMB, CND, RR, and CC are variable names (see VI.C). The RR value is calculated only for single layer constructions. The number of roots (NRT) found and the search increment (SINC) are reported as well as the values of the ROOTs and the variable RATIO. From the ROOTs and RATIOS the CTF are computed for orders zero (0 0) through (0 5) until the convergence criteria have been met. The X, Y, Z, and J CTF are reported for all orders. This report is simplified for massless constructs since no CTF (only the U value) are calculated.

DUMP OF CONDUCTION CALCULATIONS FOR:
PARTITION - STUD AREA

LAYER	L	K	CP	D	R
GYF	.016	.726	1.255	720.831	0.000
WD-S	.089	.117	1.381	512.591	0.000
GYF	.016	.726	1.255	720.831	0.000

SUMB = 254.58173 CND = 1.24059 RR = -I CC = 14368.09

NUMBER OF ROOTS = 9; SEARCH INCREMENT = .007856

N	ROOT	RATIO
1	.013546079	.516548286
2	.027011651	.072319215
3	.040288196	.002899261
4	.053198718	.000037605
5	.065446912	.000000201
6	.076662966	.000000001
7	.086835154	.000000000
8	.096795305	.000000000
9	.107590765	.000000000

NUMBER OF RESPONSE FACTORS = 5; ORDER = 2

N	0 0	0 1	0 2	0 3	0 4	0 5
1	8.683909	8.683909	8.683906	8.683909	8.683909	8.683909
2	-6.380569	-10.866227	-11.494237	-11.519418	-11.519744	-11.519746
3	-.548920	2.746952	3.532788	3.566114	3.566547	3.566549
4	-.250886	.032658	-.165999	-.176242	-.176376	-.176377
5	-.127301	.002293	-.000068	0.000000	0.000000	0.000000
1	.018542	.018542	.018542	.018542	.018542	.018542
2	.313046	.303468	.302127	.302073	.302073	.302073
3	.406281	.244577	.222631	.221755	.221743	.221743
4	.240573	.030710	.013022	.012377	.012368	.012368
5	.126555	.002288	.000067	0.000000	0.000000	0.000000
1	8.683909	8.683909	8.683906	8.683909	8.683909	8.683909
2	-6.380569	-10.866227	-11.494237	-11.519418	-11.519744	-11.519746
3	-.548920	2.746952	3.532788	3.566114	3.566547	3.566549
4	-.250886	.032658	-.165999	-.176242	-.176376	-.176377
5	-.127301	.002293	-.000068	0.000000	0.000000	0.000000
2	.588868	-.037356	0.000000	0.000000	0.000000	

Figure V.9 Dump of CTF calculations for massive construct

V.A.3.4 RNOS = 4; dump of glass calculations

Details of the optical calculations are presented beginning with the DESCRIPTION of the construction and a list of the normal transmittance, index of refraction, film transmittance, and reflectance of the GLASS or SHADE layers (AIR layers are assumed between each optical layer). The optical properties for the individual panes are:

EXTC = $k \cdot L$ from (D.3.5)

GN = index of refraction

FN = film index of refraction (D.4.1)

FK = film extinction coefficient (D.4.1)

FD = film thickness.

Then the computed reflectances and transmittances of the panes are reported at various angles of incidence:

T1 = transmittance for TE light

R11 = reflectance for TE light incident from outside

R12 = reflectance for TE light incident from inside

T2 = transmittance for TM light

R21 = reflectance for TM light incident from outside

R22 = reflectance for TM light incident from inside

The polynomial coefficients are the least squares fit values for (D.1.7b) and (D.1.7a). T refers to transmittance, A to absorptance, O to outside, I to inside, and S to shade.

DUMP OF OPTICAL CALCULATIONS FOR: 2 PANE WINDOW

LAYER	TRNS	IR	FTRN	REF
SPDS	.860	1.520	0.000	0.000
R1	0.000	1.520	0.000	0.000
SPDS	.860	1.520	0.000	0.000

OPTICAL PROPERTIES AT WAVELENGTH = .725

PANE= 1 EXTC= .065 GN=1.520 FN=0.000 FK=0.000 FD=0.000

PANE= 2 EXTC= .065 GN=1.520 FN=0.000 FK=0.000 FD=0.000

OPTICAL VALUES AT COS(THETA)= .991

PANE= 1 T1= .858 R11= .079 R12= .079 T2= .861 R21= .075 R22= .075

PANE= 2 T1= .858 R11= .079 R12= .079 T2= .861 R21= .075 R22= .075

.

OPTICAL VALUES AT COS(THETA)= .875

PANE= 1 T1= .828 R11= .106 R12= .106 T2= .882 R21= .051 R22= .051

PANE= 2 T1= .828 R11= .106 R12= .106 T2= .882 R21= .051 R22= .051

OPTICAL VALUES AT COS(THETA)= .938

PANE= 1 T1= .845 R11= .090 R12= .090 T2= .871 R21= .064 R22= .064

PANE= 2 T1= .845 R11= .090 R12= .090 T2= .871 R21= .064 R22= .064

OPTICAL VALUES AT COS(THETA)=1.000

PANE= 1 T1= .860 R11= .077 R12= .077 T2= .860 R21= .077 R22= .077

PANE= 2 T1= .860 R11= .077 R12= .077 T2= .860 R21= .077 R22= .077

Figure V.10 Dump of optical calculations

POLYNOMIAL COEFFICIENTS:

I	T2	A02	AI2	AS2	
1	3.8544537E-01	2.4276461E+00	5.7576912E-01		-I
2	1.0308017E+01	-2.2363210E+01	-3.6428286E+00		-I
3	-3.3949733E+01	1.0021852E+02	1.4986929E+01		-I
4	5.0154231E+01	-2.3554957E+02	-3.4400820E+01		-I
5	-3.9590559E+01	2.7725274E+02	3.9841064E+01		-I
6	1.4092558E+01	-1.2867078E+02	-1.8204343E+01		-I

I	T1	A01	AI1	AS1	
1	-3.8380648E-01	1.2150528E-01	1.2238673E-02		-I
2	4.4021943E+00	-1.3248196E-01	2.4052260E-01		-I
3	-6.7817725E+00	1.6526246E-01	-4.1181869E-01		-I
4	4.8351028E+00	-1.2219971E-01	2.9334734E-01		-I
5	-1.3277812E+00	3.5232619E-02	-7.9688593E-02		-I

Figure V.10 (continued)

V.A.3.5 RNOS = 5; dump of DSS data

This dump begins with the surface number (same as SRF number in V.A.2.3). Then the coordinates of the vertices of the surface are presented as X, Y, and Z values (in meters) arranged in the same order as the surface is viewed. For example, (-.000 3.113 5.150) are the X, Y, and Z coordinates respectively of the upper left vertex. (13.411 3.658 4.877) refers to the lower corner. Several individual values are then presented:

CA = cosine of the azimuth (global coordinate system) angle

SA = sine of the azimuth angle

CT = cosine of the tilt angle

ST = sine of the tilt angle

TRNS = surface transmittance

ON = start date in cyclic date (B.1.4) form

OFF = end date

S1,S2 = variables SHDSRF(I,1) and SHDSRF(I,2). See VI.C.

```

85 BUILDING 1
86 SIM(SLDS=3/HTB=0/FLOW/CNUG=.1,.01,.34,12)
87 DSS(AZM=180./TILT=153.4/ORG=0,12,16/SIZE=44,2)

SURFACE: 1
VERTICES:
      -.000      3.113      5.150      13.411      3.113      5.150
      0.000      3.658      4.877      13.411      3.658      4.877

      CA      SA      CT      ST      TRNS      ON      OFF      S1      S2
-1.000  -.000  -.894  .448  0.000    33    415      0      0

88 DSS(AZM=180./TILT=206.6/ORG=0,0,8/SIZE=44,2)

SURFACE: 2
VERTICES:
      -.000      -.545      2.165      13.411      -.545      2.165
      0.000      0.000      2.438      13.411      -.000      2.438

      CA      SA      CT      ST      TRNS      ON      OFF      S1      S2
-1.000  -.000  -.894  -.448  0.000    33    415      0      0

```

Figure V.11 Dump of shadowing surface data

V.A.3.6 RNOS = 6; dump of ZONE data

The zone data dump produces output as shown in figure 12. There are different data formats corresponding to the many different elements of zone data. Controls and scheduled loads produce similar output as shown for lines 92 through 95. First the schedule number (corresponding to CGS in V.A.2.3) is given. Then the contents of CGSZON (zone number), type of load), GGSON (on date), CGSOFF (stop date), CGSDX (week-schedule pointer), and elements 1 to 5 of RCGS (see VI.c) are given order.

Lines 96 and 101 produce dumps of heat transfer surface data. They begin with the heat transfer surface number (corresponding to HTS in V.A.2.3). On the next two lines the following values are given:

NAME	VARIABLE	DESCRIPTION
AREA	AREA	Area of surface (m2)
INV	ISENV	Zone number
ONV	OSEN	Outside environment / far side zone number
FSS	FSS	View factor to sky
FSG	FSG	View factor to ground
K	KPTR	Pointer to construct data
AZM	SFAZIM	Azimuth angle (degrees)
CTILT	CTILT	Cosine of tilt angle
HOC	HOC	Factor for detailed outside convection
THE	TMPPR	Pointer to external temperature histories
THI	TMPI	Pointer to internal temprature histories
QHE	FLXHPE	Pointer to external flux histories
QHI	FLXHPI	Pointer to internal flux histories

The surface described in line 101 is part of the envelope of the zone. Therefore, it also has shadowing surface data identical to that described in V.A.3.5.

The air flow opening at line 102 produces another dump beginning with the XREF number (corresponding to AFS). Then following variables are dumped in order:

NAME	VARIABLE	DESCRIPTION
AREA	FAREA	Effective flow area
EXP	FEXP	Flow exponent
ZS	ZS	Height of opening
ZT	ZT	Height of top of base surface
COS1	FCOS1	Direction cosine
COS2	FCOS2	Direction cosine
PTR	AFSPTR	Number of adjacent zone (0 = ambient)
ZONE	ZNMOUT	Name of adjacent zone

Other side coefficients (line 109) also produce a data dump beginning with the XREFF number (corresponding to OSC). Then the following variables are dumped in order:

```

90  ZONE C
91  GEOM(NAME=NORTH)
92  CTRL(CWS=HEATN/HEAT=12)

SCHEDULE: 1
ZON TYP  ON OFF  DX      R1      R2      R3      R4      R5
1  12  33 415  1  3514.501*****  0.000  0.000  0.000

93  PED(WS=OCCN/CAP=3)

SCHEDULE: 2
ZON TYP  ON OFF  DX      R1      R2      R3      R4      R5
1  1  33 415  1  3.000  131.800  .500  0.000  0.000

94  LIT(WS=LITN/CAP=1.4)

SCHEDULE: 3
ZON TYP  ON OFF  DX      R1      R2      R3      R4      R5
1  2  33 415  4  410.025  0.000  .200  .200  0.000

95  EQP(WS=EQPN/CAP=1.0)

SCHEDULE: 4
ZON TYP  ON OFF  DX      R1      R2      R3      R4      R5
1  3  33 415  7  292.875  0.000  .300  0.000  .700

96  MASS(CONS=PTN-A/AREA=480)

HEAT TRANSFER SURFACE: 1
  AREA  INV  ONV  FSS  FSG  K
  44.59   1  -1  0.000  0.000  3
  AZM  CTILT  HOC  THE  THI  QHE  QHI
    0.  0.000  0.000  0  0  1  1
  .
  .
  .
101  SRF(EX/OF/BS/CONS=RF-T/AZM=0/ORG=44,36,8/SIZE=41,8.95/TILT=26.6)

HEAT TRANSFER SURFACE: 5
  AREA  INV  ONV  FSS  FSG  K
  34.09   1  -3  .947  .053  7
  AZM  CTILT  HOC  THE  THI  QHE  QHI
    0.  .894  3.339  20  26  32  37

SURFACE: 7
VERTICES:
    13.411  8.534  3.660  .914  8.534  3.660
    13.411  10.973  2.438  .914  10.973  2.438

    CA  SA  CT  ST  TRNS  ON  OFF  S1  S2
    1.000  0.000  .894  .448  0.000  33  415  5  5

102  AFS(AREA=0.1/EXP=.65)

AIR FLOW SURFACE: 2
  AREA  EXP  ZS  ZT  COS1  COS2  PTR  ZONE
    .009  .650  3.049  .695  .448  0.000  0
  .
  .
  .
109  OSC(TGP=1)

OTHER SIDE COEFFICIENTS: 1
  HO  TZP  TAP  CT  CTP  TGP  WSP  HTS
  0.000  0.000  0.000  0.00  0.000  1.000  0.000  10

110  ]

```

Figure V.12 Dump of zone data

NAME	VARIABLE	DESCRIPTION
HO	RSSC(2,I)	Convection coefficient
TZP	RSSC(3,I)	Zone air temperature part
TAP	RSSC(4,I)	Ambient air temperature part
HO	RSSC(5,I)	Constant temperature
TZP	RSSC(6,I)	Constant temperature part
TAP	RSSC(7,I)	Ground temperature part
WSP	RSSC(8 I)	Wind speed factor
HTS	ISSC(9,I)	HTS number of the base surface

Movable insulation also produces a data dump from the RSSC/ISSC arrays:

NAME	VARIABLE	DESCRIPTION
R	RSSC(1,I)	Thermal resistance of insulation
A	RSSC(3,I)	Outside solar absorptance
E	RSSC(4,I)	Outside thermal emittance
RGH	ISSC(5,I)	Outside roughned number
ON	ISSC(6,I)	Start date for movable insulation
OFF	ISSC(7,I)	Stop date
CTL	ISSC(8 I)	Control type or pointer to day-schedule
HTS	ISSC(9,I)	HTS number of the base surface

V.A.3.7 RNOS = 7; dump of cross reference values

The matching of interzone partitions and openings can become difficult, so the following dump has been provided (figure V.13). As the input processor encounters interzone partitions (IZP) and openings (AFO) it checks data in two match-up lists. If the IZP/AFO does not match one of the entries in the list, it is added to the list. Otherwise, if it does match, the matched element in the list is removed. This dump monitors that process.

The first interzone partition is defined at line 104. No match for this IZP is found, so the number of unmatched IZP's is now 1. The far side and near side zone names are CENTER and NORTH, respectively. The surface area is 449.053 m²; the U-value is 8.5074 W/m²K; the number of temperature CTF terms is 3; and the number of flux CTF terms is 2. These numbers and names will be used to find the matching description of the IZP from the adjacent zone.

The air flow opening at line 105 also created an entry in the AFO table. The count and zone names are similar to those used for the IZP. The number are the opening area, flow exponent, and opening height, respectively.

The input processor continues to not find matches (lines 124, 125, 126, 148, and 149) or to match IZP and AFO (lines 127, 128, and 150). When a match is found, the reduced number of items IZP or AFO tables is reported as well as the HTS or AFS of the match. In this particular example, there is a typing error in the name of the adjacent zone at line 148. This error prevents a match of both IZP and AFO. At the conclusion of input processing

this failure to match is reported as SEVERE errors. The data accompanying the error messages (produced by default) should be sufficient to determine the incorrect or missing surfaces and openings.

```

.
.
.
104 SRF(IN/OP/BS/CONS=FTN-M/AZM=180/ORG=0,24,0/SIZE=44,12/ZONE=CENTER)
    IZF - NO MATCH: 1 CENTER NORTH 49.053 8.5074 3 2
105 AFS(AREA=0.5/EXP=.50)
    IZF - NO MATCH: 1 CENTER NORTH .04645 .500 1.829
.
.
.
124 SRF(IN/OP/BS/CONS=FTN-A/AZM=180/ORG=3,12,0/SIZE=41,12/ZONE=SOUTH)
    IZF - NO MATCH: 2 SOUTH CENTER 45.708 4.8998 1 1
125 AFS(AREA=0.5/EXP=.50)
    IZF - NO MATCH: 2 SOUTH CENTER .04645 .500 1.829
126 SRF(IN/OP/BS/CONS=PTN-S/AZM=180/ORG=0,12,0/SIZE=3,12/ZONE=SOUTH)
    IZF - NO MATCH: 3 SOUTH CENTER 3.345 1.2406 4 2
127 SRF(IN/OP/BS/CONS=PTN-M/AZM=0/ORG=44,24,0/SIZE=44,12/ZONE=NORTH)
    IZF - MATCH: NIZP = 2; HTS = 7
128 AFS(AREA=0.5/EXP=.50)
    IZF - MATCH: NUAFS = 1; AFS = 3
.
.
.
148 SRF(IN/OP/BS/CONS=PTN-A/AZM=0/ORG=44,12,0/SIZE=41,12/ZONE=CETNER)
    IZF - NO MATCH: 3 CETNER SOUTH 45.708 4.8998 1 1
149 AFS(AREA=0.5/EXP=.50)
    IZF - NO MATCH: 2 CETNER SOUTH .04645 .500 1.829
150 SRF(IN/OP/BS/CONS=PTN-S/AZM=0/ORG=3,12,0/SIZE=3,12/ZONE=CENTER)
    IZF - MATCH: NIZP = 2; HTS = 17
.
.
.
PAGE 4 NBS THERMAL ANALYSIS RESEARCH PROGRAM 82/05/14. 06.33.00. 1.733

** SEVERE UNMATCHED INTER-ZONE SURFACES:

ZONE FAR SIDE HTS AREA CONSTRUCT
CENTER SOUTH 16 45.708 PTN-A
SOUTH CETNER 28 45.708 PTN-A
** SEVERE UNMATCHED INTER-ZONE OPENINGS:

ZONE FAR SIDE AFS AREA EXP ZS
CENTER SOUTH 6 .04645 .500 1.829
SOUTH CETNER 10 .04645 .500 1.829

UNUSED LIBRARY NAMES (IF ANY):
DAY-SCHEDULE: NONE
DAY-SCHEDULE:
WEEK-SCHEDULE: CONST
** FATAL INPUT FILE NOT CREATED BECAUSE OF 'SEVERE' ERRORS

```

Figure V.13 Dump of cross reference values

V.A.4 LIBRARY REPORTS

The library data can be reported by library commands (2.1.3).

V.A.4.1 Day-schedules (DS)

Figure 14 shows typical reports for two day-schedules. A simple graph is provided with the data. The first line of the DS report is the user defined name (ON) and description (NORTH OCCUPANCY). The next line gives the schedule number / array index (3). Then comes a list of hour numbers. Below these the hourly fractions of full capacity are presented by a simple bar graph. Each hour is three X's wide. The final line of a DS report is the hourly fractions as a percent of full capacity.

```

ON          : NORTH OCCUPANCY
3:
  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
1.0 +XXXXXXXXXXXXXXXXXXXXX                                     XXX+
    +XXXXXXXXXXXXXXXXXXXXX                                     XXX+
.8  +XXXXXXXXXXXXXXXXXXXXX                                     XXX+
    +XXXXXXXXXXXXXXXXXXXXX                                     XXXXX+
.6  +XXXXXXXXXXXXXXXXXXXXX                                     XXXXX+
    +XXXXXXXXXXXXXXXXXXXXX                                     XXXXX+
.4  +XXXXXXXXXXXXXXXXXXXXX                                     XXXXX+
    +XXXXXXXXXXXXXXXXXXXXX                                     XXXXXXX+
.2  +XXXXXXXXXXXXXXXXXXXXX                                     XXXXXXX+
    +XXXXXXXXXXXXXXXXXXXXX                                     XXXXXXX+
0   +XXXXXXXXXXXXXXXXXXXXX                                     XXXXXXX+

100100100100100100 50 16  0  0  0  0  0  0  0  0  0  0  0  0  0  16 16 16 16 33 33 67100

DC          : CENTER OCCUPANCY
4:
  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
1.0 +                                                           +
    +                                                           +
.8  +                                                           +
    +                                                           +
.6  +                                                           +
    +                                                           +
.4  +                                                           +
    +                                                           +
.2  +                                                           +
    +                                                           +
0   +XXXXXXXXXXXXXXXXXXXXX                                     +

0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  17 17 17 67 50 67 17  0

```

Figure V.14 Day-schedule reports

V.A.4.2 Week-schedules (WS)

The first two lines of the week-schedule report give the user defined name, description, and the schedule number. These are followed by a list of 12 days: SUN through FRI on one line and SAT through SP4 lines below. Below each day name is the name of the day-schedule in effect on that day. Below that is the day-schedule number. Figure 15 shows three week-schedules.

```

OCCN      : NORTH OCCUPANCY
1:
  SUN      MON      TUE      WED      THU      FRI
  ON       ON       ON       ON       ON       ON
  3        3        3        3        3        3

  SAT      HOL      SP1      SP2      SP3      SP4
  ON       ON       ON       ON       ON       ON
  3        3        3        3        3        3

OCCC      : CENTER OCCUPANCY
2:
  SUN      MON      TUE      WED      THU      FRI
  OC       OC       OC       OC       OC       OC
  4        4        4        4        4        4

  SAT      HOL      SP1      SP2      SP3      SP4
  OC       OC       OC       OC       OC       OC
  4        4        4        4        4        4

OCCS      : SOUTH OCCUPANCY
3:
  SUN      MON      TUE      WED      THU      FRI
  OS       OS       OS       OS       OS       OS
  5        5        5        5        5        5

  SAT      HOL      SP1      SP2      SP3      SP4
  OS       OS       OS       OS       OS       OS
  5        5        5        5        5        5

```

Figure V.15 Week-schedule reports

V.A.4.3 Materials (MATL)

The first two lines of the materials report give the user defined name, description, and the schedule number. The thermal properties of the material are given below the names (using the input subkey names) of those properties. Optical properties are also reported when they apply.

```

MATERIALS:

GYP      : GYPSUM WALLBOARD
1:
  K      CP      D      R      A      E      RGH
  .420   .300   45.000  0.000  .75   .90   2

WD-S     : SOFTWOOD
2:
  K      CP      D      R      A      E      RGH
  .068   .330   32.000  0.000  .75   .90   2

```

Figure V.16 Materials report

V.A.4.4 Constructs (CONS)

The first two lines of the construct report give the user defined name, description, and the schedule number. The name and thermal properties of each layer are given. The number and values of the conduction transfer functions are reported. "Internal" refers to the Z functions, "cross" to the Y functions, "external" to the X functions, and "flux" to the J functions. The thermal conductance and surface properties are reported as shown below in figure 17.

Considerably more data is reported for transparent constructs. Figure V.18 shows a sample report for a double pane window. It begins with a report of the conductive properties. There is only one CTF because the layers have no thermal mass. Then the optical properties are reported. The transmittance, reflectance, and absorptances of the window are reported for 16 evenly spaced values of the cosine of the angle of incidence and for diffuse radiation. The program computes polynomial coefficients to approximate the angular dependence of these properties. These fitted values are reported for the window transmittance and absorptances at the outer and inner surfaces of the window.

PTN-S : PARTITION - STUD AREA
4:

DESCRIPTION OF CONSTRUCTION

LAYER	THICKNESS FEET	CONDUCTIVITY BTU/(HR*FT*F)	DENSITY LB/FT**3	SPECIFIC HEAT BTU/(LB*F)	RESISTANCE HR*FT**2*F/BTU
GYP	.0521	.420	45.000	.300	0.000
WD-S	.2920	.068	32.000	.330	0.000
GYP	.0521	.420	45.000	.300	0.000

5 CONDUCTION TRANSFER FUNCTIONS OF ORDER 2

TIME	INTERNAL	CROSS	EXTERNAL	FLUX
1	1.53034770	.00326766	1.53034770	.58886750
2	-2.02560683	.05324329	-2.02560683	-.03735637
3	.62257626	.03923376	.62257626	
4	-.02925375	.00229484	-.02925375	
5	-.00001205	.00001179	-.00001205	

THERMAL CONDUCTANCE = .219 BTU/(HR*FT**2*F)
 OUTER THERMAL ABSORPTANCE = .90
 INNER THERMAL ABSORPTANCE = .90
 OUTER SOLAR ABSORPTANCE = .75
 INNER SOLAR ABSORPTANCE = .75
 OUTER SURFACE ROUGHNESS =ROUGH

Figure V.17 Constructs report

WDW2 : 2 PANE WINDOW
5:

DESCRIPTION OF CONSTRUCTION

LAYER	THICKNESS FEET	CONDUCTIVITY BTU/(HR*FT*F)	DENSITY LB/FT**3	SPECIFIC HEAT BTU/(LB*F)	RESISTANCE HR*FT**2*F/BTU
SPDS	0.0000	0.000	0.000	.200	.024
R1	0.0000	0.000	0.000	.200	.910
SPDS	0.0000	0.000	0.000	.200	.024

1 CONDUCTION TRANSFER FUNCTIONS OF ORDER 0

TIME	INTERNAL	CROSS	EXTERNAL	FLUX
1	1.04471375	1.04471375	1.04471375	

THERMAL CONDUCTANCE = 1.045 BTU/(HR*FT**2*F)
OUTER THERMAL ABSORPTANCE = .90
INNER THERMAL ABSORPTANCE = .90
OUTER SOLAR ABSORPTANCE = .75
INNER SOLAR ABSORPTANCE = .75
OUTER SURFACE ROUGHNESS =ROUGH

OPTICAL VALUES

LAYER	TRNS	IR	FTRN	TRNS	REF
SPDS	.860	1.520	0.000		
SPDS	.860	1.520	0.000		

ANGULAR DEPENDENCE OF VALUES:

COS(THETA):	.0625	.1250	.1875	.2500	.3125	.3750	.4375	.5000
TRANSMITTANCE:	.0563	.1548	.2639	.3705	.4647	.5415	.6003	.6434
REFLECTANCE:	.8314	.7109	.5932	.4830	.3875	.3109	.2532	.2119
ABSORPTANCE:	.0872	.0975	.0982	.0959	.0926	.0893	.0862	.0835
ABSORPTANCE:	.0251	.0368	.0447	.0507	.0552	.0584	.0603	.0612

FITTED VALUES FOR LOADS CALCULATIONS:

TRANSMITTANCE:	.0568	.1540	.2643	.3708	.4645	.5412	.6004	.6436
OUTER ABSORPTANCE:	.0855	.1002	.0971	.0944	.0932	.0906	.0859	.0822
INNER ABSORPTANCE:	.0249	.0371	.0446	.0505	.0553	.0585	.0603	.0611

ANGULAR DEPENDENCE OF VALUES:

COS(THETA):	.5625	.6250	.6875	.7500	.8125	.8750	.9375	1.00 DIFFUSE
TRANSMITTANCE:	.6743	.6962	.7117	.7228	.7308	.7366	.7409	.7440 .6554
REFLECTANCE:	.1832	.1639	.1511	.1429	.1380	.1352	.1341	.1341 .2089
ABSORPTANCE:	.0811	.0788	.0767	.0747	.0728	.0709	.0691	.0673 .0782
ABSORPTANCE:	.0615	.0611	.0605	.0595	.0584	.0572	.0559	.0546 .0575

FITTED VALUES FOR LOADS CALCULATIONS:

TRANSMITTANCE:	.6742	.6963	.7118	.7228	.7307	.7366	.7410	.7439 .6554
OUTER ABSORPTANCE:	.0811	.0788	.0767	.0747	.0728	.0709	.0691	.0673 .0782
INNER ABSORPTANCE:	.0615	.0612	.0605	.0595	.0584	.0572	.0559	.0546 .0575

Figure V.18 Construct report for a window

V.A.4.5 Control profiles (CPFL)

The first two lines of the control profile report give the user defined name, description, and the schedule number. The next line is a list of the user defined control temperatures followed by a line of matching fractions of full capacity. The number of control points is determined by the user subject to array dimension constraints. Figure 19 shows this report for two control profiles.

```
CONTROL PROFILES:
P1          : HEATING SETBACK
1:
  TMP:  60.000  62.000
  CAP:   1.000   0.000
P2          : STANDARD HEATING
2:
  TMP:  68.000  70.000
  CAP:   1.000   0.000
```

Figure V.19 Control profiles reports

V.A.4.6 Control day-schedules (CDS)

After the two line of standard heading information the CDS report gives a list of 24 hours (on four lines) with the profile name and index reported below each hour. Figure 20 shows a CDS report for two control day-schedules.

V.A.4.7 Control week-schedules (CWS)

The first lines of the control week-schedule report give the user defined name, description, and the schedule number. These are followed by a list of 12 days: SUN through FRI on one line and SAT through SP4 four lines below. Below each day name is the name of the control day-schedule in effect on that day. Below that is the control day schedule number. Figure 21 shows two control week-schedules.

CONTROL DAY-SCHEDULES:

HN : NORTH HEATING

1:

1	2	3	4	5	6
P1	P1	P1	P1	P1	P1
1	1	1	1	1	1
7	8	9	10	11	12
P2	P2	P1	P1	P1	P1
2	2	1	1	1	1
13	14	15	16	17	18
P1	P1	P1	P1	P2	P2
1	1	1	1	2	2
19	20	21	22	23	24
P2	P2	P2	P2	P1	P1
2	2	2	2	1	1

HC : CENTER HEATING

2:

1	2	3	4	5	6
P1	P1	P1	P1	P1	P1
1	1	1	1	1	1
7	8	9	10	11	12
P1	P1	P1	P1	P1	P1
1	1	1	1	1	1
13	14	15	16	17	18
P1	P1	P1	P1	P2	P2
1	1	1	1	2	2
19	20	21	22	23	24
P2	P2	P2	P2	P1	P1
2	2	2	2	1	1

Figure V.20 Control day-schedule reports

CONTROL WEEK-SCHEDULES:

HEATN : NORTH HEATING

1:

SUN	MON	TUE	WED	THU	FRI
HN	HN	HN	HN	HN	HN
1	1	1	1	1	1
SAT	HOL	SP1	SP2	SP3	SP4
HN	HN	HN	HN	HN	HN
1	1	1	1	1	1

HEATC : CENTER HEATING

2:

SUN	MON	TUE	WED	THU	FRI
HC	HC	HC	HC	HC	HC
2	2	2	2	2	2
SAT	HOL	SP1	SP2	SP3	SP4
HC	HC	HC	HC	HC	HC
2	2	2	2	2	2

Figure 21. Control week-schedule reports

V.B LOADS REPORTS

V.B.1 DEFAULT REPORTS

Sample default output of the loads calculator program is shown in figure 22. The loads calculator is designed to be recompiled to match the specific problem being simulated. The user may decide to store different compilations on tape. Therefore, the first action of the loads calculator program is not to print the maximum available array space so the user can determine the capabilities of the program by executing it, even without a simulation input file (SINPFL). The names for the array sizes match those reported by the input processor as described in V.A.1 and VI.C. If the user has attached a SINPFL, the program prints the array space required to solve the current simulation. If insufficient space is available, a warning is given, and execution is terminated. Otherwise, simulation begins. If the available array space is much too large, it may be desirable to compile so that just sufficient space is available and charges for program size during execution are minimized. During the calculation of the solar gain multipliers, two other array requirements are reported: the shadowing combinations (CMB) and homogeneous coordinate space (HCS). These sizes depend on the number of surfaces, the shadowing algorithm (3.1.2), and the specific arrangement of surfaces and so they cannot be known before program execution.

The next default report is shown as page 2 in figure 22. It describes the calculational effort used to determine the building loads. First, the temperature and flux history initialization period is reported. The execution time for initialization can be determined by comparing the completion time with the start time (which was given with the page 2 header). Initialization proceeds until load and temperature extreme values for two successive days are within the convergence limits. In this example that required seven days. There were 635 surface and air heat balances, or about 3.78 iterations per hour. This number can be reduced by widening the convergence limits. That will also result in fewer days for initialization. Wider convergence limits tend to change peak values more than they change the total loads. There were 2181 Newton's method iterations to compute air flows. That is about 3.43 iterations per heat balance iteration. There were no heat balance iterations which failed to converge. Failure to converge may be due to an inadequate iteration limit (3.1.3) or to cycling between points on two different segments of a control profile. The loads for that hour may or may not be reasonable. Check the peak loads (below) for impossible values. Similar information on time, days, and iterations is given for the simulation period.

The final summary of building loads is presented as page 3 of the example. The report is headed by three descriptions: project (1.1.1), location (1.3.1), and weather (1.5.1 or 1.6.1). Then the following values are presented for each zone: Total heating and cooling requirements, peak heat and cooling loads, maximum and minimum zone air temperatures, hours at peak heating capacity (HX), other heating hours (HT), ventilating hours (V), cooling (below peak capacity) hours (CL), and hours at peak cooling capacity (CX). Building-wide values are summarized by the line labeled "TOTAL:" These values include the total heating and cooling requirements for all zones, the peak coincident heating and cooling

loads, and the maximum and minimum of all zone temperatures. The hour and day are reported for the occurrence of the peak loads and temperatures. In the example, there is no time reported for peak cooling since there was no cooling load.

PAGE 1 NBS THERMAL ANALYSIS RESEARCH PROGRAM 82/05/17. 05.38.06. 3.004

MRLP MAXIMUM ARRAY DIMENSIONS:

ZON:	4
SRF:	36
HTS:	36
AFS:	24
CGS:	16
GTP:	4
TFH:	512
CTF:	192
SSC:	16
DSH:	16
WSH:	16
CON:	16
PFL:	8
CDS:	8
CWS:	8

MRLP ARRAY SPACE USED:

ZON:	3
SRF:	32
HTS:	32
AFS:	10
CGS:	12
GTP:	1
TFH:	283
CTF:	140
SSC:	3
DSH:	11
WSH:	10
CON:	11
PFL:	2
CDS:	3
CWS:	3

REQUIRED CMB = 82

REQUIRED HCS = 10

Figure V.22 Default loads calculation output

PAGE 2 NBS THERMAL ANALYSIS RESEARCH PROGRAM 82/05/17. 05.38.09. 3.469

BEGIN TEMPERATURE AND FLUX HISTORIES INITIALIZATION

INITIALIZATION COMPLETE AT TIME 5.576

7 DAYS SIMULATED
635 HEAT BALANCE ITERATIONS
2181 AIR FLOW ITERATIONS
0 ITERATIONS DID NOT CONVERGE

SIMULATION COMPLETE AT TIME 7.867

1 DAYS SIMULATED
100 HEAT BALANCE ITERATIONS
335 AIR FLOW ITERATIONS
0 ITERATIONS DID NOT CONVERGE

PAGE 3 NBS THERMAL ANALYSIS RESEARCH PROGRAM 82/05/17. 05.38.17. 7.868

BUILDING LOADS FOR

THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN

COLUMBIA, MO.

MILD WINTER

ZONE	TOTAL HEATING (KBTU)	TOTAL COOLING (KBTU)	PEAK HEATING (KBTUH)	PEAK COOLING (KBTUH)	MAX TEMP (F)	MIN TEMP (F)	HX	HT	V	CL	CX
NORTH	52.29	0.00	10.300	0.000	69.26	61.89	0	11	0	0	0
CENTER	1.45	0.00	1.292	0.000	73.00	64.01	0	2	0	0	0
SOUTH	.56	0.00	.563	0.000	77.64	67.78	0	1	0	0	0
TOTAL:	5.430E+01 0.		10.863	0.000	77.64	61.89					

MAX HEATING OCCURS AT HOUR 7 ON 21FEB

MAX TEMP OCCURS AT HOUR 18 ON 21FEB

MIN TEMP OCCURS AT HOUR 6 ON 21FEB

Figure V.22 (continued)

V.B.2 NUMBERED REPORTS

Several reports and data dumps can be requested by specifying report numbers (1.2.1).

V.B.2.1 RNOS = 8; Dump of SINPFL as read by loads program

This is a dump of every value transferred from the input processor to the loads calculator by the simulation input file (SINPFL). It includes all project data except the weather and can, therefore, be rather long. Figure 23 for a SINPFL dump of the sample problem data is four pages long.

The SINPFL dump begins with a dump of variables which can be described as run control data. Refer to VI.C for a description of the individual variables. Next comes a dump of library data beginning with the day-schedules. The data for each day-schedule consists of the array index, the schedule name, and 24 hours of capacity fractions expressed as percents. The week-schedules are dumped in a similar manner. Each line describes one schedule and consists of an array index, the schedule name, and 12 pointers to day-schedule array indices.

There is no data for materials. All materials have been used in constructs. The headings for the constructs data are:

NAME	VARIABLE	DESCRIPTION
NT	NTRTFC	Number of temperature CTF terms
PE	TRTFPE	Pointer to external (X) CTF terms
PC	TRTFPC	Pointer to cross (Y) CTF terms
PI	TRTFPI	Pointer to internal (Z) CTF terms
NF	NFRTFC	Number of flux CTF terms
PF	FLRTFP	Pointer to flux CTF terms
XO	CTFXO	X CTF for time=0
YO	CTFYO	Y CTF for time=0
ZO	CTFZO	Z CTF for time=0
AO	OSABS	Outside solar absorptance
EO	OTABS	Outside thermal emittance
AI	ISABS	Inside solar absorptance
EI	ITABS	Inside thermal absorptance
VF	IVABSF	Multiplier for diffuse solar absorptance
U	UVAL	Thermal conductance of construct
R	OROUGH	Outside roughness number
W	WTYPE	Pointerr to window array index

The conduction transfer functions are listed directly from the CTF array at ten numbers per line. The construct pointer values (PE, PC, and PI) point to the location immediately before CTF location. For example, the X(1) value of WL-S is -6.3074297 (PE = 7; therefore CTF index = 8). The X(0), Y(0), and Z(0) values are stored separately. The window pointer, WTYPE, points to the array index of the window coefficients. In this example, there is only one window type, but each type has four line of data: one each for transmittance

and outside, inside, and shade absorptance. Each line of data consists of the window type index, data abbreviation, value for diffuse radiation, and polynomial coefficients for angular properties.

Control profile data consists of the array index, profile name, number of control points, and control temperatures and capacity fractions. In the example, the capacities for P1 are 1.0 at T=15.56 and 0.0 at T=16.67. The control day-schedule data consists of the array index, schedule name, and 24 pointers to control profile array indices. The control week-schedule data consists of the array index, schedule name, and 12 pointers to control day-schedule array indices.

Inputs (4.2) through (4.11) create scheduled loads and activities. Each line of the scheduled loads dump consists of the array index, zone number (CGSZON), type (CGSTYP), start and stop dates (CGSON and CGSOFF), schedule pointer (CGSDF), all 5 values of RCGS, and zone names (CGSZON). See VI.C for descriptions of these variables.

Next the surfaces involved in shadowing and solar gains (SRF) are described. This consists first of the array index, number of vertices, and X, Y, and Z coordinates of the vertices for each surface. Then comes the subsurface data previously described in V.A.3.5.

The heading for the columns of data for the heat transfer surfaces (HTS) are:

NAME	VARIABLE	DESCRIPTION
AREA	AREA	Area of surface
Z	ISENV	Zone number
ONV	OSENV	Outside environment / far side zone number
FSS	FSS	View factor to sky
FSG	FSG	View factor to ground
SSC	SSCPTR	Pointer to special coefficients
K	KPTR	Pointer to construct data
THE	TMPHPE	Pointer to external temperature histories
THI	TMPHPI	Pointer to internal temperature histories
FHE	FLXHPE	Pointer to external flux histories
FHI	FLXHPI	Pointer to internal flux histories
AZM	SFAZIM	Azimuth angle (degrees)
CTILT	CTILT	Cosine of tilt angle
HOC	HOC	Factor for detailed outside convection

The special coefficient data consists of the array index and nine values from ISSC or RSSC (see VI.C) depending on the type of data being described (see also V.A.3.6). Special surface coefficients are stored at the bottom of the array and movable insulation data are stored at the top.

TRANSFER FUNCTIONS:														
1	-2.5278906	.0007745	.0585821	.0000064	-3.9713113	.0023383	.0005898	-6.3074297	2.1913321	-1.1701522				
11	-.0001604	.1303580	.1530421	.0182837	.0003167	-13.2198161	5.2871352	-.4435605	-.0006664	.7875525				
21	-.0944633	-3.5941588	.3969768	-3.5941588	.0000000	-11.4942369	3.5327878	-.1659994	-.0000684	.3021272				
31	.2226306	.0130220	.0000669	-11.4942369	3.5327878	-.11659994	-.0000684	.5888675	-.0373564	-2.7764006				
41	.0339609	1.1996385	.0093482	-2.7764006	.0339609	.0320282	-16.8168694	15.3861333	-6.2155929	1.0945002				
51	-.0726984	.0012641	.0000941	.0029472	.0093951	.0060339	.0009344	.0000372	-20.8567580	19.5905340				
61	-8.1700639	1.4917542	-.1027480	.0018451	1.8687430	-1.1559223	.2754416	-.0292241	.0004788	-3.6880357				
71	.0001720	.0299762	.0000004	-3.1848037	.0003207	.0001007	-36.6001481	7.3391719	-.1604196	2.8850762				
81	1.2008836	.0286105	-36.6001481	7.3391719	-1.604196	.4948389	-.0190345	-22.0509244	24.4059857	-11.8667380				
91	2.3390075	-.1257694	-.0005882	-.0000127	-.0000003	.0000066	.0001889	.0006341	.0004705	.0001002				
101	.0000084	.0000004	.0000000	-6.3591088	5.3795972	-1.7329740	.1629810	-.0009349	-.0000293	-.0000011				
111	-.0000000	2.4347023	-2.0132431	.6308696	-.0534117	-18.4101751	16.8112578	-6.7871467	1.1601606	-.0580476				
121	-.0002645	-.0000056	.0001719	.0034217	.0080983	.0039974	.0004949	.0000204	.0000005	-87.6863367				
131	80.8926204	-31.3375508	4.8604217	-.2553859	-.0000927	-.0000001	1.9360081	-1.2650689	.3252876	-.0257356				
WINDOW COEFFICIENTS:														
1	T	.65542	-.38381	4.40219	-6.78177	4.83510	-1.32778	.38545	10.30802	-33.94973	50.15423	-39.59056	14.09256	
1	A0	.07823	.12151	-.13248	.16526	-.12220	.03523	2.42765	-22.36321	100.21852	-235.54957	277.25274	-128.67078	
1	A1	.05746	.01224	.24052	-.41182	.29335	-.07969	.57577	-3.64283	14.98693	-34.40082	39.84106	-18.20434	
1	AS	0.00000	-I	-I	-I	-I	-I	-I	-I	-I	-I	-I	-I	
CONTROL PROFILES:														
1	P1	2	15.56	1.00	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	P2	2	20.00	1.00	21.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CONTROL DAY-SCHEDULES:														
1	HN	1	1	1	1	1	1	1	1	1	1	2	2	1
2	HC	1	1	1	1	1	1	1	1	1	1	2	2	1
3	HS	1	1	1	1	1	1	1	1	1	1	2	2	1
CONTROL WEEK-SCHEDULES:														
1	HEATN	1	1	1	1	1	1	1	1	1	1	2	2	1
2	HEATC	2	2	2	2	2	2	2	2	2	2	2	2	1
3	HEATS	3	3	3	3	3	3	3	3	3	3	2	2	1
SCHEDULED LOADS:														
1	Z	1	12	33	415	WS	1	3514.501*****	0.000	0.000	0.000	0.000	0.000	NORTH
2	1	1	33	415	1	3	3,000	131.800	.500	0.000	0.000	0.000	0.000	NORTH
3	1	2	33	415	4	4	410.025	0.000	.200	.200	0.000	0.000	0.000	NORTH
4	1	3	33	415	7	7	292.875	0.000	.300	0.000	0.000	.700	0.000	NORTH
5	2	12	33	415	2	2	3514.501*****	0.000	0.000	0.000	0.000	0.000	0.000	CENTER
6	2	1	33	415	2	3	3,000	131.800	.500	0.000	0.000	0.000	0.000	CENTER
7	2	2	33	415	5	5	410.025	0.000	.200	.200	0.000	0.000	0.000	CENTER
8	2	3	33	415	8	8	292.875	0.000	.300	0.000	0.000	.700	0.000	CENTER
9	3	12	33	415	3	3	3514.501*****	0.000	0.000	0.000	0.000	0.000	0.000	SOUTH
10	3	1	33	415	3	3	3,000	131.800	.500	0.000	0.000	0.000	0.000	SOUTH
11	3	2	33	415	6	6	410.025	0.000	.200	.200	0.000	0.000	0.000	SOUTH
12	3	3	33	415	9	9	2753.026	0.000	.300	.400	.300	.300	.300	SOUTH

Figure V.23 (continued)

SURFACES:

SURFACES:

1	4	-0.0	3.11	5.15	0.00	3.66	4.88	13.41	3.66	4.88	13.41	3.66	4.88	13.41	3.11	5.15
2	4	-0.0	-0.25	2.17	0.00	0.00	2.44	13.41	-0.00	2.44	13.41	-0.00	2.44	13.41	-0.25	2.17
3	4	0.00	11.25	2.98	0.00	0.00	10.97	-13.41	10.97	2.44	-13.41	10.97	2.44	-13.41	11.25	2.98
4	4	13.41	10.97	2.44	13.41	10.97	0.00	9.1	10.97	0.00	9.1	10.97	0.00	9.1	10.97	2.44
5	4	3.66	2.13	-0.8	3.66	1.52	-0.8	9.75	1.52	-0.8	9.75	1.52	-0.8	9.75	2.13	-0.8
6	4	9.1	10.97	2.44	9.1	10.97	0.00	0.00	10.97	0.00	0.00	10.97	0.00	0.00	10.97	2.44
7	4	13.41	8.53	3.66	13.41	10.97	2.44	9.1	10.97	2.44	9.1	10.97	2.44	9.1	8.53	3.66
8	4	9.1	8.53	3.66	9.1	10.97	2.44	0.00	10.97	2.44	0.00	10.97	2.44	0.00	8.53	3.66
9	4	-0.0	7.32	3.66	0.00	7.32	0.00	13.41	7.32	0.00	13.41	7.32	0.00	13.41	7.32	3.66
10	4	-0.0	10.97	2.44	0.00	10.97	0.00	-0.0	7.32	0.00	-0.0	7.32	0.00	-0.0	10.97	2.44
11	4	13.41	7.32	3.66	13.41	7.32	0.00	13.41	7.32	0.00	13.41	7.32	0.00	13.41	7.32	3.66
12	4	-0.0	7.32	-0.0	0.00	10.97	0.00	13.41	10.97	0.00	13.41	10.97	0.00	13.41	7.32	-0.0
13	4	-0.0	3.66	4.57	0.00	3.66	3.66	13.41	3.66	3.66	13.41	3.66	3.66	13.41	3.66	4.57
14	4	6.1	9.1	-0.8	6.1	0.00	-0.8	12.80	0.00	-0.8	12.80	0.00	-0.8	12.80	9.1	-0.8
15	4	13.41	4.88	4.88	13.41	7.32	3.66	9.1	7.32	3.66	9.1	7.32	3.66	9.1	4.88	4.88
16	4	9.1	4.88	4.88	9.1	7.32	3.66	0.00	7.32	3.66	0.00	7.32	3.66	0.00	4.88	4.88
17	4	9.1	3.66	3.66	9.1	3.66	0.00	13.41	3.66	0.00	13.41	3.66	0.00	13.41	3.66	3.66
18	4	-0.0	3.66	3.66	0.00	3.66	0.00	9.1	3.66	0.00	9.1	3.66	0.00	9.1	3.66	3.66
19	4	13.41	7.32	3.66	13.41	7.32	0.00	0.00	7.32	0.00	0.00	7.32	0.00	0.00	7.32	3.66
20	4	-0.0	7.32	3.66	0.00	7.32	0.00	-0.0	3.66	0.00	-0.0	3.66	0.00	-0.0	3.66	4.88
21	4	13.41	3.66	4.88	13.41	3.66	0.00	13.41	3.66	0.00	13.41	3.66	0.00	13.41	7.32	3.66
22	4	-0.0	3.66	-0.0	0.00	7.32	0.00	13.41	7.32	0.00	13.41	7.32	0.00	13.41	3.66	-0.0
23	4	-0.0	-0.0	2.44	0.00	0.00	0.00	12.50	0.00	0.00	12.50	0.00	0.00	12.50	-0.0	2.44
24	4	3.66	2.13	-0.8	3.66	9.1	-0.8	9.75	9.1	-0.8	9.75	9.1	-0.8	9.75	2.13	-0.8
25	4	12.50	-0.0	2.44	12.50	0.00	0.00	13.41	0.00	0.00	13.41	0.00	0.00	13.41	-0.0	2.44
26	4	0.00	2.44	3.66	0.00	0.00	0.00	12.50	0.00	2.44	12.50	0.00	2.44	12.50	0.00	2.44
27	4	12.50	2.44	3.66	12.50	0.00	0.00	13.41	0.00	2.44	13.41	0.00	2.44	13.41	2.44	3.66
28	4	13.41	3.66	3.66	13.41	3.66	0.00	9.1	3.66	0.00	9.1	3.66	0.00	9.1	3.66	3.66
29	4	9.1	3.66	3.66	9.1	3.66	0.00	0.00	3.66	0.00	0.00	3.66	0.00	0.00	3.66	3.66
30	4	-0.0	3.66	3.66	0.00	3.66	0.00	13.41	3.66	0.00	13.41	3.66	0.00	13.41	3.66	3.66
31	4	13.41	-0.0	2.44	13.41	0.00	0.00	13.41	0.00	0.00	13.41	0.00	0.00	13.41	3.66	3.66
32	4	-0.0	0.00	-0.0	0.00	3.66	0.00	13.41	3.66	0.00	13.41	3.66	0.00	13.41	-0.0	-0.0
		CA	SA	CT	SI	S2	DN	OFF	TRANS							
1	-1.000	-0.000	-0.894	.448	0	0	33	415	0.000							
2	-1.000	-0.000	-0.894	-0.448	0	0	33	415	0.000							
3	1.000	0.000	-0.448	.894	0	0	33	415	0.000							
4	1.000	0.000	-0.000	1.000	2	2	0	0	0.000							
5	1.000	0.000	-0.000	1.000	3	-2	0	0	0.000							
6	1.000	0.000	-0.000	1.000	4	4	0	0	0.000							
7	1.000	0.000	.894	.448	5	5	0	0	0.000							
8	1.000	0.000	.894	.448	6	6	0	0	0.000							
9	-1.000	-0.000	-0.000	1.000	7	7	0	0	0.000							
10	.000	-1.000	-0.000	1.000	8	8	0	0	0.000							
11	-0.000	1.000	-0.000	1.000	9	9	0	0	0.000							
12	-1.000	-0.000	-1.000	-0.000	10	10	0	0	0.000							
13	-1.000	-0.000	-0.000	1.000	12	12	0	0	0.000							
14	-1.000	-0.000	-0.000	1.000	13	-12	0	0	0.000							
15	1.000	0.000	.894	.448	14	14	0	0	0.000							
16	1.000	0.000	.894	.448	15	15	0	0	0.000							
17	-1.000	-0.000	-0.000	1.000	16	16	0	0	0.000							
18	-1.000	-0.000	-0.000	1.000	17	17	0	0	0.000							
19	1.000	0.000	-0.000	1.000	18	18	0	0	0.000							
20	.000	-1.000	-0.000	1.000	19	19	0	0	0.000							
21	-0.000	1.000	-0.000	1.000	20	20	0	0	0.000							
22	-1.000	-0.000	-1.000	-0.000	21	21	0	0	0.000							
23	-1.000	-0.000	-0.000	1.000	23	23	0	0	0.000							
24	-1.000	-0.000	-0.000	1.000	24	-23	0	0	0.000							
25	-1.000	-0.000	-0.000	1.000	25	25	0	0	0.000							
26	-1.000	-0.000	.894	.448	26	26	0	0	0.000							
27	-1.000	-0.000	.894	.448	27	27	0	0	0.000							
28	1.000	0.000	-0.000	1.000	28	28	0	0	0.000							
29	1.000	0.000	-0.000	1.000	29	29	0	0	0.000							
30	.000	-1.000	-0.000	1.000	30	30	0	0	0.000							
31	-0.000	1.000	-0.000	1.000	31	31	0	0	0.000							
32	-1.000	-0.000	-1.000	-0.000	32	32	0	0	0.000							

Figure V.23 (continued)

HEAT TRANSFER SURFACES:																		
	AREA	Z	ONV	FSS	FSG	SSC	K	THE	THI	FHE	FHI	AZM	CTLT					
1	44.59	1	-1	0.00	0.00	0	3	0	0	1	1	0	0.00	0.00				0.00
2	30.47	1	-3	.50	.50	0	1	2	4	6	7	0	-0.00	3.36				3.36
3	3.72	1	-3	.50	.50	0	5	8	8	8	8	0	-0.00	3.36				3.36
4	2.23	1	-3	.50	.50	0	2	8	12	16	18	0	-0.00	5.88				5.88
5	34.09	1	-3	.95	.05	0	7	20	26	32	37	0	.89	3.34				3.34
6	2.49	1	-3	.95	.05	0	8	42	44	46	47	0	.89	6.04				6.04
7	49.05	1	2	18	T	0	9	131	48	134	51	180	-0.00	0.00				0.00
8	11.15	1	-2	.50	.50	0	9	53	53	56	56	270	-0.00	0.00				0.00
9	11.15	1	-2	.50	.50	0	9	58	58	61	61	90	-0.00	0.00				0.00
10	49.05	1	-4	0.00	1.00	16	10	63	71	79	83	180	-1.00	1.30				1.30
11	44.59	2	-1	0.00	0.00	0	3	87	87	88	88	0	0.00	0.00				0.00
12	12.26	2	-3	.50	.50	0	6	89	91	93	94	180	-0.00	5.52				5.52
13	11.15	2	-3	.50	.50	0	5	95	95	95	95	180	-0.00	5.52				5.52
14	34.09	2	-3	.95	.05	0	7	95	101	107	112	0	.89	3.44				3.44
15	2.49	2	-3	.95	.05	0	8	117	119	121	122	0	.89	6.21				6.21
16	45.71	2	3	28	T	0	3	218	123	219	124	180	-0.00	0.00				0.00
17	3.34	2	3	29	T	0	4	220	125	224	129	180	-0.00	0.00				0.00
18	49.05	2	1	.50	.50	0	9	136	136	139	139	270	-0.00	0.00				0.00
19	15.61	2	-2	.50	.50	0	9	141	141	144	144	90	-0.00	0.00				0.00
20	15.61	2	-2	.50	.50	0	9	146	154	162	166	180	-1.00	1.30				1.30
21	49.05	2	-4	0.00	1.00	15	10	170	170	171	171	0	0.00	0.00				0.00
22	44.59	3	-1	0.00	0.00	0	3	170	170	171	171	0	0.00	0.00				0.00
23	30.47	3	-3	.50	.50	0	1	172	174	176	177	180	-0.00	3.36				3.36
24	7.43	3	-3	.50	.50	0	5	178	178	178	178	180	-0.00	3.36				3.36
25	2.23	3	-3	.50	.50	0	2	178	182	186	188	180	-0.00	5.88				5.88
26	34.09	3	-3	.95	.05	0	7	190	196	202	207	180	.89	3.34				3.34
27	2.49	3	-3	.95	.05	0	8	212	214	216	217	180	.89	6.04				6.04
28	45.71	3	2	16	T	0	3	123	218	124	219	0	-0.00	0.00				0.00
29	3.34	3	2	17	T	0	4	125	220	129	224	0	-0.00	0.00				0.00
30	11.15	3	-2	.50	.50	0	9	226	226	229	229	270	-0.00	0.00				0.00
31	11.15	3	-2	.50	.50	0	9	231	231	234	234	90	-0.00	0.00				0.00
32	49.05	3	-4	0.00	1.00	14	11	236	243	250	254	180	-1.00	1.30				1.30

SPECIAL COEFFICIENTS:

16	3	0.000	0.000	0.000	0.000	0.000	1.000	0.000	10
15	3	0.000	0.000	0.000	0.000	0.000	1.000	0.000	21
14	3	0.000	0.000	0.000	0.000	0.000	1.000	0.000	32

AIR FLOW SURFACES:

	AREA	FEXP	ZS	ZV	FCOS1	FCOS2	PTR	NAME
1	.0186	.650	1.22	.64	1.000	0.000	0	
2	.0093	.650	3.05	.70	.448	0.000	0	
3	.0465	.500	1.83	.70	0.000	0.000	2	CENTER
4	.0232	.650	4.11	.73	-1.000	-0.000	0	
5	.0093	.650	4.27	.74	.448	0.000	0	
6	.0465	.500	1.83	.70	0.000	0.000	3	SOUTH
7	.0465	.500	1.83	.70	0.000	0.000	1	NORTH
8	.0186	.650	1.22	.64	-1.000	-0.000	0	
9	.0093	.650	3.05	.70	.448	-0.000	0	
10	.0465	.500	1.83	.70	0.000	0.000	2	CENTER

ZONE RELATED VALUES:

	NAME	FSRF	LSRF	FHTS	LHTS	FAFS	LAFS	ZZ	VMULT	VCONV
1	NORTH	4	12	1	10	1	3	1.500	.0056	0.0000
2	CENTER	13	22	11	21	4	7	1.500	.0047	0.0000
3	SOUTH	23	32	22	32	8	10	1.500	.0055	0.0000

Figure V.23 (continued)

The headings for the air flow opening data are:

NAME	VARIABLE	DESCRIPTION
FAREA	FAREA	Effective flow area
FEXP	FEXP	Flow exponent
ZS	ZS	Height of opening
ZV	ZVMOD	Factor for wind pressure calculation
FCOS1	FCOS2	Direction cosine
FCOS2	FCOS2	Direction cosine
PTR	AFSPTR	Number of adjacent zone (0=ambient)
NAME	AFSNAM	Name of adjacent zone

The zone related values consist of the array index, the zone name, the indices of the first and last surfaces which are part of the zone, the first and last heat transfer surface numbers, the first and last air flow surface numbers, the height of the zone for pressure calculations, and multipliers for visible and convective gains.

V.B.2.2 RNOS = 9; Zone description report

This report gives a description of each zone (one zone per page). It begins with the zone name, for example, NORTH in figure V.24. Next is a listing of the scheduled loads and controls. The data is presented using the input variable names. The surfaces of the zone are described next. The first zone includes a description of the detached shadowing surfaces. The reported U-values do not include surface coefficients. Finally, the air flow openings are described. ZONE is the name of the zone on the other side of the opening.

DESCRIPTION OF ZONE NORTH

SCHEDULED LOADS AND CONTROLS

TYPE	SCHEDULE	FROM	THRU	DATA
CTRL	HEATN	1JAN	31DEC	HEAT= 1.20E+04 COOL= 3.41E+09 RAD=0.00
FEO	OCCN	1JAN	31DEC	CAP= 3.00E+00 ACT= 4.50E+02 RAD= .50
LIT	LITN	1JAN	31DEC	CAP= 1.40E+03 RA=0.00 RAD= .20 VIS= .20 REP=0.00
ERP/EL	EQPN	1JAN	31DEC	CAP= 1.00E+03 LAT=0.00 RAD= .30 LOST=0.00

SURFACES

TYPE	AZM	TILT	AREA	U	CONSTRUCT	ZONE	FROM	THRU	TRNS
DET. SHADE	180.	153.					1JAN	31DEC	.000
DET. SHADE	180.	153.					1JAN	31DEC	.000
DET. SHADE	0.	117.					1JAN	31DEC	.000
ENVELOPE	0.	90.	328.00	.049	WL-I				
WINDOW	0.	90.	40.00	1.045	WDW2				
ENVELOPE	0.	90.	24.00	.176	WL-S				
ENVELOPE	0.	27.	366.95	.100	RF-T				
ENVELOPE	0.	27.	26.85	.033	RF-I				
INTERZONE	180.	90.	528.00	1.499	PTN-M	CENTER			
PARTITION	270.	90.	120.00	1.499	PTN-M				
PARTITION	90.	90.	120.00	1.499	PTN-M				
USER DEFND	180.	180.	528.00	.081	SLAB-C				

AIR FLOW OPENINGS

AREA	EXP	ZS	ZONE
.0186	.65	1.22	AMBIENT
.0093	.65	3.05	AMBIENT
.0465	.50	1.83	CENTER

Figure V.24 Zone description report

V.B.2.3 RNOS = 13; Report of sunlit fractions

This report gives the fraction sunlit area for all heat transfer surfaces. It begins with the date and solar declination and equation of time values used in computing the solar position. The values of the cosine of the angle of incidence on each surface and the sunlit fraction are presented for 24 hours on the half hour. Nine values from ISSC or RSSC (see VI.C) depending on the They are in the HTS number sequence. The sunlit fractions apply only to the outside of envelope surfaces, so partitions and such cannot have sunlit fractions but are reported to maintain the sequence of surfaces.

RESULTS OF SHADOWING CALCULATIONS

```

DATE = 21FEB      SIN(DECL) = -.1875      COS(DECL) = .9823      EON OF TIME = -.2299

FORM OF DATA: / COSINE OF INCIDENCE, SUNLIT FRACTION /

STANDARD TIME = 0:30
/ -I, -I / -I,0.000 / -I,0.000 / -I,0.000 / -I,0.000 / -I,0.000 / -I,0.000 /
/ -I,0.000 / -I,0.000 / -I, -I / -I,0.000 / -I,0.000 / -I,0.000 / -I,0.000 /
/ -I,0.000 / -I,0.000 / -I,0.000 / -I,0.000 / -I, -I / -I,0.000 / -I,0.000 /
/ -I,0.000 / -I,0.000 / -I,0.000 / -I,0.000 / -I,0.000 / -I,0.000 / -I,0.000 /
,
,
,

STANDARD TIME = 10:30
/ -I, -I / -.689,0.000 / -.689,0.000 / -.689,0.000 / .188,1.000 / .689,0.000 / -.465,0.000 /
/ .465,0.000 / -.556,0.000 / -I, -I / .689, .091 / .689, .929 / .188,1.000 / .689,0.000 /
/ .689,0.000 / -.689,0.000 / -.465,0.000 / .465,0.000 / -.556,0.000 / -I, -I / .689, .545 / .689, .610 /
/ .689, .766 / .805,1.000 / .805,1.000 / -.689,0.000 / -.689,0.000 / -.465,0.000 / -.556,0.000 /

STANDARD TIME = 11:30
/ -I, -I / -.746,0.000 / -.746,0.000 / -.746,0.000 / .226,1.000 / .746,0.000 / -.225,0.000 /
/ .225,0.000 / -.626,0.000 / -I, -I / .746, .091 / .746, .928 / .226,1.000 / .746,0.000 /
/ .746,0.000 / -.746,0.000 / -.225,0.000 / .225,0.000 / -.626,0.000 / -I, -I / .746, .542 / .746, .596 /
/ .746, .727 / .894,1.000 / .894,1.000 / -.746,0.000 / -.746,0.000 / -.225,0.000 / -.626,0.000 /
,
,
,

REQUIRED HCS = 10

```

Figure V.25 Results of shadowing calculations

Some surfaces of the building can never be shaded by others because of various geometric constraints. TARP does a one-time determination of which surfaces can possibly be shaded by others and stores the results to save time in long term or multiple environment runs. The shadowing combinations report for the example problem is shown in figure 26. Information is presented for each General Shadow Receiving Surface (GRS), that is, each Exterior, Base Surface (4.13.2) of the building. Surfaces are referred to by their SRF numbers. The first such surface is GRSNR = 4. For this surface there is one possible shadowing surface (NGSS = 1), seven interior surfaces which may receive direct sun through the window (NBKS = 7), and one subsurface (NSBS = 1) (4.13.2). A general shadowing surface (GSS) is either a GRS or a detached shadowing surface (3.2). The one GRS which might shade GRS #4 is SRF #3. The detailed solar distribution within the zone must refer to the Exterior of Interior (4.13.2) surfaces which are called back surfaces (BKS) during shadowing calculations. The seven back surfaces which might receive beam sunlight through the window are SRFs #6, 7, 8, 9, 10, 11, and 12. The only subsurface of the GRS is SRF #5. Note that GRS #6 has no (transparent) SBS and therefore no BKS need be computed.

PAGE 4 NBS THERMAL ANALYSIS RESEARCH PROGRAM 82/05/11. 14.04.45. 3.182

SHADOWING COMBINATIONS

GRSNR = 4	NGSS = 1	NBKS = 7	NSBS = 1
GSSNR = 3			
BKSNR = 6 7 8 9 10 11 12			
SBSNR = 5			
GRSNR = 6	NGSS = 1	NBKS = 0	NSBS = 0
GSSNR = 3			
GRSNR = 7	NGSS = 0	NBKS = 0	NSBS = 0
GRSNR = 8	NGSS = 0	NBKS = 0	NSBS = 0
GRSNR = 13	NGSS = 3	NBKS = 8	NSBS = 1
GSSNR = 1 26 27			
BKSNR = 15 16 17 18 19 20 21 22			
SBSNR = 14			
GRSNR = 15	NGSS = 0	NBKS = 0	NSBS = 0
GRSNR = 16	NGSS = 0	NBKS = 0	NSBS = 0
GRSNR = 23	NGSS = 1	NBKS = 8	NSBS = 1
GSSNR = 2			
BKSNR = 25 26 27 28 29 30 31 32			
SBSNR = 24			
GRSNR = 25	NGSS = 1	NBKS = 0	NSBS = 0
GSSNR = 2			
GRSNR = 26	NGSS = 2	NBKS = 0	NSBS = 0
GSSNR = 1 13			
GRSNR = 27	NGSS = 2	NBKS = 0	NSBS = 0
GSSNR = 1 13			
REQUIRED CMB = 82			

Figure V.26 Shadowing combinations report

V.B.2.5 RNOS = 15, 16; Dump of shadowing calculations

The shadowing calculation dumps are intended for checking the shadow calculation process. They produce a large amount of output. Figure V.27 shows part of the output for only one hour. Report 15 provides summary results such as a record of which subroutines were called and the net results of the calculations. Report 16 gives the details of the homogeneous coordinate calculations. The output from 16 is printed as the calculations occur, and so it is intermingled with report 15. The output consists of subroutine names (see VI.B) and variable names (see VI.C) with values. To use this report, follow the calculations through the program listing and simultaneously through the report.

```

STANDARD TIME = 10:30
/ -1 / -.689,0.000 / -.689,0.000 / -.689,0.000 / / .188,1.000 / .188,1.000 / .689,0.000 / -.465,0.000 /
/ .465,0.000 / -.556,0.000 / -1 / .689, .091 / / .689, .929 / .188,1.000 / .188,1.000 / .689,0.000 /
/ .689,0.000 / -.689,0.000 / -.465,0.000 / .465,0.000 / -1 / .689, .545 / .689, .610 / .689, .610 /
/ .689, .766 / .805,1.000 / .805,1.000 / -.689,0.000 / / -.689,0.000 / -.465,0.000 / .465,0.000 / -.556,0.000 /

DUMP OF SHADOWING CONTROL DATA
EOTM=-.230 SIND=-.188 COSD=.982 SUNCOS(I)= .225 -.746 .626

BEGIN SHDGRS: GRSNR= 4 HTS= 2 CTHETA(GRSNR)=-.746 NGSS= 1 NBKS= 7 NSRS= 1 LOCSCM= 1
SHDGRS: GRSNR= 5 HTS= 3
END SHDINT: DB(NZ)= 0.000 DS(NZ)= 1.218 DG(NZ)= 1.218
END SRG: SAREA(HTSS)= 0.000 NSRSHC= 0 NRULHC= 0 TRM=0.00 ABD= .75 ARI=0.00 CBI=0.00
END SHDGRS: GRSNR= 4 HTS= 2 SAREA(HTS)= 0.000

BEGIN SHDGRS: GRSNR= 6 HTS= 4 CTHETA(GRSNR)=-.746 NGSS= 1 NBKS= 0 NSRS= 0 LOCSCM= 14
END SHDGRS: GRSNR= 6 HTS= 4 SAREA(HTS)= 0.000

BEGIN SHDGRS: GRSNR= 7 HTS= 5 CTHETA(GRSNR)= .226 NGSS= 0 NBKS= 0 NSRS= 0 LOCSCM= 19
END SHDGRS: GRSNR= 7 HTS= 5 SAREA(HTS)= 34.091

BEGIN SHDGRS: GRSNR= 8 HTS= 6 CTHETA(GRSNR)= .226 NGSS= 0 NBKS= 0 NSRS= 0 LOCSCM= 23
END SHDGRS: GRSNR= 8 HTS= 6 SAREA(HTS)= 2.494

BEGIN SHDGRS: GRSNR= 13 HTS=12 CTHETA(GRSNR)= .746 NGSS= 3 NBKS= 8 NSRS= 1 LOCSCM= 27
HCGRS: NS= 1 NV=4 AREA= 12.258 C= .302 S= .839
HC: 13411 914/ 13411
SHDGRS: GRSNR= 1 CTHETA(GRSNR)=-.226
HCGRS: NS= 2 NV=4 AREA= -2.468 T=0.00
HC: 13411 1219/ 13247 1035/ -164
OVLAP: NS1= 1 NS2= 2 NS3= 2 NIN1=0 NIN2=0 NV3=0 MISS=1 AREA= -2.468 T=0.00
SHDGRS: GRSNR= 26 CTHETA(GRSNR)= .894
SHDGRS: GRSNR= 27 CTHETA(GRSNR)= .894
END SHDGRS: SAREA(HTS)= 12.258 NGSSHC= 0
SHDGRS: BKSNR= 15 CTHETA(BKSNR)= .226 FBKSHC= 2 NBKSHC= 0
SHDGRS: BKSNR= 16 CTHETA(BKSNR)= .226 FBKSHC= 2 NBKSHC= 0
SHDGRS: BKSNR= 17 CTHETA(BKSNR)= .746 FBKSHC= 2 NBKSHC= 0
SHDGRS: BKSNR= 18 CTHETA(BKSNR)= .746 FBKSHC= 2 NBKSHC= 0
SHDGRS: BKSNR= 19 CTHETA(BKSNR)= .746 FBKSHC= 2 NBKSHC= 0
HCRKS: NS= 2 NV=4 AREA= -49.044 T=0.00
HC: 14514 3069/ 14514 -588/ 1103
OVLAP: NS1= 1 NS2= 2 NS3= 2 NIN1=2 NIN2=0 NV3=4 MISS=4 AREA= -588/ 1103 T=1.00
HC: 1103 0/ 1103 914/ 13411
SHDGRS: BKSNR= 20 CTHETA(BKSNR)=-.225 FBKSHC= 2 NBKSHC= 1
HCRKS: NS= 3 NV=4 AREA= -4.707 T=0.00
HC: 1103 3069/ 1103 -588/ 0
OVLAP: NS1= 1 NS2= 3 NS3= 3 NIN1=2 NIN2=0 NV3=4 MISS=4 AREA= -588/ 0 T=1.00
HC: 0 0/ 1103 914/ 1103
SHDGRS: BKSNR= 21 CTHETA(BKSNR)= .225 FBKSHC= 2 NBKSHC= 2
SHDGRS: BKSNR= 22 CTHETA(BKSNR)=-.626 FBKSHC= 2 NBKSHC= 2
HCRKS: NS= 4 NV=4 AREA= -41.172 T=0.00
HC: 0 -3658/ 14514 -588/ 13411
OVLAP: NS1= 1 NS2= 4 NS3= 4 NIN1=0 NIN2=0 NV3=0 MISS=1 AREA= -588/ -41.172 T=1.00
END SHDGRS: NBKSHC= 2

```

Figure V.27 Dump of shadowing calculations

V.B.2.6 RNOS = 21; Hourly dump of primary zone loads data

This report provides hourly loads data. It consists of a line of time data, a line of weather data, and a line of loads data for each zone (see figure V.28). All data are in metric units. The time data consists of:

STDTIM standard time; ts in (III.B.1.1)
CLKTIM clock time.; td in (III.B.1.1)
DAYOFS number of days simulated (including current day)
DAYOFY day of year; DY in (B.1.2)
MONTH month number
DAYOFM day of month
DAYOFW day of week; DW in (B.1.7)
DAYTYP day type; pointer to schedules
CDATE cyclic date; CD in (B.1.4)

The weather data consists of:

DB dry-bulb temperature
WB wet-bulb temperature
BP barometric pressure
SPD wind speed
DIR wind direction
TS sky temperature
HB direct normal solar flux
HD sky brightness
HR ground brightness
TG ground temperature

The zone loads data consists of:

TZ zone air temperature
TR zone radiant temperature
SN sensible load (+ = heating, - = cooling)
LA latent gain from internal sources
EE energy for lights and electric equipment
GE energy for steam equipment
ST energy for gas equipment
HW energy for hot water equipment
OT energy for other equipment
RA energy direct to return air
BB baseboard load
OAMFL mass flow rate of outside air into zone

V.B.2.7 RNOS = 21, 22, 23, 24; Dump of zone loads calculations

Reports 22, 23, and 24 give details of the loads calculation process. All are in metric units. These dumps can be quite lengthy. Figure 29 shows part of the output generated for one hour. Report 21 should be specified to report times for the other reports.

Report 22 describes the control profiles and solar gains for the hour. The report of control values describes the control profile (IV.E) for each zone. It consists first of the zone number, the number of control temperature ranges (NRCTR), and the temperature range which will be used for the first air heat balance (EFSTR). The second line is a list of control point temperatures. It is followed by the QFSTDC and QFSTIF variables for the control ranges between the indicated temperatures. The solar gains data consists first of the total short wavelength (including from lights) flux (W/m^2) absorbed by each heat transfer surface on the outside (QSO), the inside (QSI), and on any movable insulation (QSM). Then the radiant gains converted directly to convection (QC), the total diffuse solar gain (QD), the total diffuse shortwave radiant gain (QS), the total beam sunlight into the zone (QBV), and the total diffuse sunlight into the zone (QDV).

The following dumps (23) describe the heat balance calculations. They begin with the airflow calculations. The following data is presented for each airflow opening (I).

N	(inside) zone number
M	(far side) zone number (0 = ambient)
PS	stack pressure (G.2.3)
PW	wind pressure (G.1.3)
PZ	zone pressure
DP	pressure difference across opening
FLOW	mass flow rate through opening (+ = in, - = out)

Then the partial outside (KOP) and partial inside (KIP) conductive fluxes (C.1.7 and C.1.5) are presented for each heat transfer surface. These values are constant for the hour. The convection coefficients (HC) are also presented for each surface followed by the outside surface temperatures (TO) and then the inside surface temperatures (TI). The results of the zone air heat balances are summarized under ZON:

TZ	zone air temperature
TR	zone mean radiant temperature
ET	effective temperature
CT	control temperature range
VT	ventilation control range
SL	sensible load (+ = heat, - = cool)
LL	latent load
SUMC	sum of direct convective loads
QL	total longwave radiant gains
PZ	zone air pressure

The FLOW, TI and ZON values are dumped for each heat balance iteration. HC and TO may also be dumped if new values are computed.

Report 24 is a dump of the contents of the temperature and flux histories array. It occurs after heat balances have converged. The hourly shift of the histories is accomplished by the TSHIFT variable until it equals zero and the histories are moved. NTFH is the number of temperature and flux histories. The histories are matched to their respective heat transfer surfaces by the TMPHPE, TMPHPI, FLXHPE, and FLXHPI pointers which can be obtained by reports 6 or 8. Report 21 then summarizes the zone loads for the hour.

```

TIME: STDTIM=17; CLKTIM=17; DAYOFS= 1; DAYOFY= 52; MONTH= 2; DAYOFM=21; DAYOFW=2; DAYTYP= 2; CI
WEATHER: DB= 8.89; WR= 3.86; BP=100000.; SPD= 6.7; DIR=315.; TS= -8.12; HB=675.5; HD= 40.9; I
CONTROL: ZONE= 1; NRCTR=3; EFSTR=1
  CONTEM: -98.000 20.000 21.111 98.000
  QFSTDC: 0. -3.163E+03 0.
  QFSTIF: 3.515E+03 6.678E+04 0.
CONTROL: ZONE= 2; NRCTR=3; EFSTR=3
  CONTEM: -98.000 20.000 21.111 98.000
  QFSTDC: 0. -3.163E+03 0.
  QFSTIF: 3.515E+03 6.678E+04 0.
CONTROL: ZONE= 3; NRCTR=3; EFSTR=3
  CONTEM: -98.000 20.000 21.111 98.000
  QFSTDC: 0. -3.163E+03 0.
  QFSTIF: 3.515E+03 6.678E+04 0.
QSD: 0.000 30.890 3.278 30.890 41.927 41.927 0.000 0.000
      0.000 0.000 0.000 51.047 27.444 41.927 41.927 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 160.489 21.825
      200.228 240.603 240.514 0.000 0.000 0.000 0.000 0.000
QSI: .535 .535 2.463 .535 .535 .535 .535 .535
      .535 .535 2.851 2.851 19.673 2.851 2.851 2.851
      2.851 16.057 2.851 51.005 2.851 2.053 2.053 15.643
      2.053 2.053 2.053 2.053 2.053 2.053 15.217 13.679
QSM: 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000

      QC      QD      QS      QBV      QDV
      1 0.      1.274E+02 7.130E-01 0.      1.003E+02
      2 0.      8.084E+02 3.801E+00 2.053E+03 3.009E+02
      3 0.      4.971E+02 2.737E+00 1.052E+03 2.006E+02
FLOW: 1 N M FS PW PZ DP FLOW
      1 1 0 -18.06 2.57 -19.75 4.25820 161.67
      2 1 0 -18.72 -1.14 -19.75 -1.11059 -7.42
      3 1 2 .06 0.00 -19.75 -.98394 -153.97
      4 2 0 -19.60 -3.30 -20.79 -2.10995 -125.08
      5 2 0 -19.69 -1.27 -20.79 -.16838 -9.67
      6 2 3 .02 0.00 -20.79 -.01496 -18.83
      7 2 1 -.06 0.00 -20.79 .98394 153.97
      8 3 0 -17.99 -2.57 -20.83 .27151 27.01
      9 3 0 -19.10 -3.61 -20.83 -1.88684 -46.41
      10 3 2 -.02 0.00 -20.83 .01496 18.83
KOP: 91.796 28.722 .000 54.964 81.925 46.633 771.327 771.327
      771.327 46.261 91.796 59.301 .000 82.829 46.871 91.796
      199.303 771.327 771.327 771.327 46.923 91.796 41.915 .000
      85.136 133.525 76.771 91.796 199.303 771.327 771.327 49.593
KIP: 71.786 71.192 -.000 138.661 131.319 57.395 698.483 603.115
      603.115 39.761 91.968 70.383 -.000 162.679 73.416 93.171
      197.591 760.825 747.766 765.739 44.098 96.059 95.667 -.000
      192.235 174.818 77.400 94.865 202.337 765.428 761.470 794.945

```

Figure V.29 Dump of zone loads calculations

VI. COMPUTER PROGRAM

The general structure of the Thermal Analysis Research Program was described in chapter II.B and figure II.1. This chapter expands upon that introduction by describing the program subroutines, variables, and files.

VI.A INPUT PROCESSOR

The input processor (IP) is the first of the two TARP subprograms. It checks and interprets the user input, creates the input files for the loads calculator (LC), and writes various reports. This processing involves all of chapter IV and primarily sections B, C, and D of chapter III. Data about the location and weather goes to the LC in the ENVTFIL (environment file). The description of the building, including library data, goes in the SINPFL (simulation input file).

The IP is divided into four major sections corresponding to the input language sections. These sections may be used to reduce core requirements by overlay (or segmentation). A small input processor will help to give fast job turn-around necessary to quickly debug the user input deck. Each section is headed by a subroutine that is called when a section name and "[" is encountered in the input. The name of that routine is similar to the section name. The section processor subroutines all have similar structures, especially for how they handle incorrect input.

Each section contains several subroutines which process the input language keys. The names of these routines are the same as the key names. Most of the key processing routines also have similar structures consisting of: initialization, decoding the subkeys, error checking, calculation of derived data, output to SINPFL, reports and dumps. The output to SINPFL consists of an identifier record containing two integers and one or (sometimes) more data records. The data records usually have values for a single surface, schedule, etc., which is read by the LC into arrays for all surfaces, schedules, etc.

Some key processing subroutines call other groups of subroutines for complex calculations. The largest of these groups are those that compute the conduction transfer functions and the window optical coefficients.

A short description of each of the 130 input processor subroutines is given below. After the descriptions is a diagram (figure VI.A.1) showing the general relationship of the IP routines and the segment structure.

```
AFS                                     subroutine
```

Evaluate the subkeys of AFS (4.14). The AFSDAT common block contains data to match interzone openings. Data is output in the AFSIL common block.

BBH subroutine
Evaluate the subkeys of BBH (4.11). Data is output in the SSCISL common block.

BDLIB block data
Set initial values for library processing.

BDPROJ block data
Set initial values for project processing.

BDSLRL block data
Set initial values for processing user input.

BEAM subroutine
Evaluate window optical properties for beam sunlight at 16 angles of incidence.

BLANK(ARRAY,LEN) subroutine
Blank (set to ' ') an ARRAY of character strings of length LEN.

BUILDG subroutine
Evaluate the keys of BUILDING (section 3). This is the root subroutine of the building segment.

CDS subroutine
Evaluate the subkeys of CDS (2.7). Convert control profile names to pointers.

CHKCP subroutine
Check description of control profile: number, range, and order of temperatures and normalized capacities.

COMPMS subroutine
Compute the optical properties for the pane-shade system for both polarizations of light incident from the outside. Compute overall transmittance and reflectance and individual absorptances.

CONS	subroutine
<p>Evaluate the subkeys of CONS (2.5). Evaluate the thickness of each layer, and convert its material name to a pointer to retrieve material data from unit 4. Compute conduction transfer functions. Compute optical coefficients for constructs having no opaque layers. Data is written to the constructs file (unit 5) for reference by zone surfaces. Data is output to the SINPFL in common blocks CONDAT, GLAS, and GLAS0.</p>	
CPFL	subroutine
<p>Evaluate the subkeys of CPFL (2.6). Call CHKCP to check the control profile. Data is output in the CNTPFL common block.</p>	
CREPT(SCRFL)	subroutine
<p>Transfer constructs reports (2.1.3) from unit SCRFL to the output file.</p>	
CTRL	subroutine
<p>Evaluate the subkeys of CTRL (4.9). Data is output in the CGSIL common block.</p>	
CTF(I,CONVG)	subroutine
<p>Calculate the higher order conduction transfer functions from the response factors (order 0 CTF) and the RATIO's. Check convergence by (C.2.1).</p>	
CWS	subroutine
<p>Evaluate the subkeys of CWS (2.8). Convert control day-schedule names to pointers.</p>	
DCHXYZ	subroutine
<p>Compute conduction transfer functions of a single layered slab using the algorithm of D. C. Hittle.</p>	
DDY	subroutine
<p>Evaluate the subkeys of DDY (1.6). Data is output as a single day in the ENVTFIL.</p>	
DER	subroutine
<p>Calculate the total construct and total derivative matrices for a single value of the Laplace parameter.</p>	

DIFFUS

subroutine

This subroutine operates in one of two modes. It may compute the optical properties of a combination of glass panes for both polarizations of diffuse light of a given wavelength incident from both sides (D.6.2). Or it may compute the optical properties of a pane-shade system for both polarizations of diffuse light of a given wavelength incident from the outside only. A Simpson's rule integration is used.

DIFSHD

subroutine

Compute the reflectance of an interior shading device for both polarizations of diffuse light.

DLT

subroutine

Evaluate the subkeys of DLT (4.10). Data is output in the CGSIL common block.

DMPAFS

subroutine

Dump air flow opening data in the AFSIL common block. Dump initiated by RNOS=6 (1.2.1).

DMPCGS

subroutine

Dump zone control and general schedule data in the CGSIL common block. Dump initiated by RNOS=6 (1.2.1).

DMPHTS

subroutine

Dump heat transfer surface data in the HTSIL, HTSIS, and HTSISL common blocks. Dump initiated by RNOS=6 (1.2.1).

DMPSRF

subroutine

Dump surface geometry data in the SRFIS common block. Dump initiated by RNOS=6 (1.2.1).

DMPSSC

subroutine

Dump special surface data in the SSCISL common block. Dump initiated by RNOS=6 (1.2.1).

DS

subroutine

Evaluate the subkeys of DS (2.2). Check number and range of profile values.

subroutine

```
DUMPGl(MODE)                               subroutine
```

```
DUMPLB                                subroutine
```

DUMPNV subroutine

DUMPPJ subroutine

DUMPRF(MODE) subroutine

DUPLIB(LO,LEN) subroutine

DYS(JFLAG,DY,MO,DM,LY) subroutine

EMI subroutine

201

EQP

subroutine

Evaluate the subkeys of EQP (4.4). Data is output in the CGSIL common block.

ERROR(MSG,ETYPE)

subroutine

Print error message (character string MSG). Process according to error type (ETYPE).

ETYPE=0: informative message.

ETYPE=1: 'warning' -- unusual, but not fatal, input.

ETYPE=2: 'severe' -- input error which will prevent running LC.
COUNT of type 2 errors may not exceed 30.

ETYPE=3: 'fatal' -- immediate run termination.

ETYPE<0: set ETYPE to the highest ETYPE number with which ERROR was ever called.

EXTCF(TO,N)

real function

Compute $k*L$ (extinction coefficient times thickness) of glass pane N with normal incidence transmittance TO (D.3.11).

FAN

subroutine

Evaluate the subkeys of FAN (4.8). Data is output in the CGSIL common block.

FILM(J,N,LAMBDA,CTHETA,STHETA,CPhi)

subroutine

Compute the optical properties of a thin reflective film on side J (1=outside, 2=inside) of glass pane N.

FINDFD(N,TPLAIN,TFILM)

subroutine

Determine the thickness of a thin reflective film on pane N by its normal transmittance with (TFILM) and without (TPLAIN) the film.

FINISH

subroutine

Finish input processing. Check for and report unmatched interzone surfaces and openings. Check for and report unused library names. Terminate run if there were any 'severe' errors. Report minimum LC array sizes (PARAMETERS). Write the last SINPFL record - common block RUNCTL.

GEOM

subroutine

Evaluate the subkeys of GEOM (4.1). Values are set for the subsequent geometric processing of zone surfaces.

GETB3W(NSKIP,NDAYS)

subroutine

Skip NSKIP days of weather data from the BLAST 3.0 weather file (WTH RTP, unit 3). Transfer the following NDAYS of data to the ENVTFIL.

GETLIN

subroutine

Get the next line on user input from the INPUT file. Echo the line in the output file. Print error message if data is being skipped.

GLASSX

subroutine

Compute the total transmittance and reflectance of a system of up to four panes of glass and the absorptance of each pane for both polarizations of light and both directions of incidence (at a given wavelength and angle of incidence).

GRND

subroutine

Evaluate the subkeys of GRND (1.4). Data goes into ENVTFIL header record.

ICTF

subroutine

Initialize arrays for conduction transfer function calculations.

IDSTF(MO,DM,DW)

integer function

IDSTF = 1 when daylight savings time is in effect, and it equals 0 otherwise. IDSTF is based on the month number (MO), the day-of-month (DM), and the day-of-week (DW). Daylight savings time begins on the last Sunday in April, and it continues until standard time resumes on the last Sunday of October.

ILLINI(A,B,TOL,RT,REPEAT)

subroutine

Use modified false position method to compute root (RT) in the interval bounded by A and B. Convergent solution is found the upper bound - lower bound < TOL. If solution is not found, set REPEAT to true.

IMI

subroutine

Evaluate the subkeys of IMI (4.18). Data is output in the SSCISL common block.

INF

subroutine

Evaluate the subkeys of INF (4.5). Data is output in the CGSIL common block.

INITCF

subroutine

Compute the units conversion factors. Most factors are derived from $CFL(2)=.3048$, $CFM(2)=.45359237$, and $CFC(2)=4.184$ to give a consistent set of conversion factors.

INITGL

subroutine

Direct the calculation of window optical coefficients. Set up properties of optical layers (no air layers). Set coefficients of shading coefficients window directly. Otherwise, evaluate optical properties (SPCTRM) and compute polynomial coefficients (WDWPOL). Print dumps and reports as required. This is the root subroutine of the optical calculations segment.

INITRF

subroutine

Direct calculation of conduction transfer functions. Compute properties of conductive layers (no interior shades). Evaluate CTF for multi-layer (RESPNS) or single layer (DCHXYZ) constructs and report results. This is the root subroutine of the conduction calculations segment.

INTCON(ANUM,EFLAG)

integer function

Evaluate character string ANUM as an integer (syntax rule [IV.B.1] 8). If ANUM is a proper integer, return EFLAG set to 0. Otherwise, set INTCON to 0, set EFLAG to 1, and print error message.

ISHADE

subroutine

Add the effect of an interior shade to optical properties of the glass panes in the window (D.7).

IZERO(ARRAY,LEN)

subroutine

Set ARRAY (length LEN) of integers to 0.

JDS(JFLAG,JD,YR,MO,DM)

subroutine

If JFLAG = 1, compute the Julian date (JD) from the year (YR), month (MO), and day-of-month (DM) (B.1.2). Otherwise, compute YR, MO, and DM from YR (B.1.3).

LIB

subroutine

Evaluate the subkeys of LIB (2.1). Data is used to control the processing of library input. Open the library report scratch files.

LIBRRY

subroutine

Evaluate keys of LIBRARY (section 2.). Insure sequence of key input. This is the root subroutine of the library segment.

LIT

subroutine

Evaluate the subkeys of LIT (4.3). Data is output in the CGSIL common block.

LOC

subroutine

Evaluate the subkeys of LOC (1.3). Data is stored in the weather file header (common block EFLHDR).

LOCLIB(ITEM,L0,LEN,LOC)

subroutine

Determine location (LOC) of ITEM in the library relative to L0. The library consists of seven groups of named elements. All names in the seven groups are stored in the LNAMEs array beginning at various locations. L0 is the array location before the first entry in the group of interest. LEN is the number of elements of that group. LOC records the sequence in which the library entries were defined and in which they exist on scratch files or will exist in the loads calculator arrays. If ITEM is not found, set LOC to zero.

LOCORD(LIST,LEN,ITEM)

integer function

Determine the location of ITEM in a LEN long array (LIST) of alphabetically ordered words. If ITEM is not found, return the value zero. A bisection search is used.

LOCNAN(LIST,LEN,ITEM)

integer function

Determine the location of ITEM in a LEN long array (LIST) or unordered words. If ITEM is not found, return the value zero. A linear search is used.

LREPT(SCRFL,NLINES,TITLE)

subroutine

Transfer library reports (2.1.3) from unit SCRFL to the output file. Each report element is NLINES long and is given a TITLE. Close the SCRFL when finished.

LSQFIT(ITYPE,N,N1,N2)

subroutine

Compute the polynomial coefficients of the optical properties equations (D.1.7a and b). A standard least squares fit is used.

ITYPE = 1 does the polynomial which is evaluated by POLY1F.

ITYPE = 2 does the polynomial which is evaluated by POLY2F.

N is the order of the polynomial.

N1 is the location in X and Q of the first data value.

N2 is the location in X and Q of the last data value.

LYF(YR)

integer function

Compute the leap year indicator from the four digit year number (YR).
If YR is a leap year, set LYF to 1. Otherwise set LYF to 0.

MASS

subroutine

Evaluate the subkeys of MASS (4.12). Thermal properties are read from
UNIT 5. Data are output in common blocks HTSIL and HTSISL.

MATL

subroutine

Evaluate the subkeys of MATL (2.4). The input data are checked against
appropriate ranges. The material properties are written to UNIT 4 for
reference by the CONS subroutine. The materials report (MATL - 2.1.3)
is written to UNIT 23.

MATRIX(W)

subroutine

Evaluate the conduction matrix for a multi-layered slab.

MIX

subroutine

Evaluate the subkeys of MIX (4.7). Data is output in the CGSIL common
block.

MODY(DATE,EFLAG)

integer function

Evaluate character string DATE as a date (syntax rule [IV.b.1] 10).
Compute MODY in the cyclic date form (B.1.4). If DATE is a valid date,
return EFLAG set to 0. Otherwise, set MODY to 0, set EFLAG to 1, and
print error message. Note that day-of-month numbers from 1 through 31
are considered valid for all months.

OSC

subroutine

Evaluate the subkeys of OSC (4.16). Data is output in the SSCISL
common block. Error checking includes (1) OSC not permitted with
interior surface, (2) OSC not permitted with EMI on same surface, and
(3) multiple definitions of OSC for the same surface not permitted.

PAGE(IACT,NEED)

subroutine

Write output report page headings. This routine can be used to count the number of lines being printed on issue page eject commands at appropriate intervals according to the use of IACT and NEED.

IACT=0: Initialize page routine. Set page length to NEED.

IACT=1: NEED lines are to be printed. If there is insufficient space remaining on the page, eject page and print heading.

IACT=2: Return page number in NEED.

IACT=3: Return number of lines left on page in NEED.

IACT=4: Eject page and print heading if NEED lines not left on page. Do not increment line count.

The page heading includes a report of cumulative program execution time determined from the non-ANSI function SECOND. This function can be removed without otherwise affecting the program.

PANE(N)

subroutine

Compute the transmittance, reflectance and absorptance of pane number N (counted from the outside). This routine uses the optical algorithms of III.D.3.

PEO

subroutine

Evaluate the subkeys of PEO (4.2). Data is output in the CGSIL common block.

POLY1F(X,A,N)

real function

Evaluate simple polynomial expression (D.1.7a):

$$P = A(1) + A(2)*X + A(3)*X^2 + \dots + A(N)*X^{N-1}$$

POLY2F(X,A,N)

real function

Evaluate simple polynomial expression (D.1.7b):

$$P = A(1)*X + A(2)*X^2 + \dots + A(N)*X^N$$

PROJECT

subroutine

Open the simulation input (SINPFL) and environment (ENVTFIL) files. Evaluate the keys of PROJECT (section 1.). Write the weather file header record and close the weather file. Write the first records on the simulation input file. Initiate dump of "project" data (RNOS=1 - 1.2.1). This is the root subroutine of the project segment.

PSYCH

subroutine

This routine may be used to test the psychrometric package. It is not called by TARP.

PSYDPW(W,PB)

real function

Compute the dew point temperature (TD) from the humidity ratio (W) and the barometric pressure (PB) (B.2.6).

PSYHTW(TA,W)

real function

Compute the enthalpy (H) from the dry bulb temperature (TA) and humidity ratio (W) (B.2.9).

PSYRHT(TA,TD)

real function

Compute the relative humidity (RH) from the dry bulb (TA) and dew point (TD) temperatures (B.2.7). Check for $0 < RH < 1$.

PSYTDW(TA,W,PB)

real function

Compute the wet bulb temperature (TW) from the dry bulb temperature (TA), humidity ratio (W), and the barometric pressure (PB). TW is computed by iteration of function PSYWTP to a convergent solution. The first set is to check for saturated air which means $TW = TA$. Failing that, an initial guess for TW is made at $TA - 1$. This initial guess is increased if it produces an impossibly low humidity ratio. The initial guess is used in a secant iteration. If the secant iteration should fail, a slower but more reliable bisection iteration is available.

PSYVTW(TA,W,PB)

real function

Compute the specific volume (V) of moist air from the dry bulb temperature (TA), humidity ratio (W), and barometric pressure (PB) (B.2.8). Check for reasonable range: $0.58 < V < 3$.

PSYWDP(TD,PB)

real function

Compute humidity ratio (W) from dew point temperature (TD) and barometric pressure (PB) (B.2.2). Check for $W > 1.61E-6$ (W for $TD = -70C$).

PSYWTH(TA,H)

real function

Compute humidity ratio (W) from dry bulb temperature (TA) and enthalpy (H) (B.2.5). Check for $W > 1.61E-6$ (W for $TD = -70C$).

PSYWTP(TA,TW,PB)

real function

Compute humidity ratio (W) from dry bulb (TA) and wet bulb (TW) temperatures and barometric pressure (PB) (B.2.3). Check for $W > 1.61E-6$ (W for $TD = -70C$).

PSYWTR(TA,RH,PB)

real function

Compute humidity ratio (W) from dry bulb temperature (TA), relative humidity (RH), and barometric pressure (PB) (B.2.4). Check for $W > 1.61E-6$ (W for TD = -70C).

QTF

subroutine

Compute flux conduction transfer coefficients from RATIO values.

RC

subroutine

Evaluate the subkeys of RC (1.1). Data are stored in the RUNCTL common block and used in subsequent processing of user input.

READER

subroutine

Decode the user input (in UINREC) according to input syntax rules (IV.B.1). Output is current status (UISTAT) and individual words in the AWORD array. The longest element of input processed in one call to this routine is a subkey with data.

RELCON(ANUM,EFLAG)

real function

Evaluate character string ANUM as a real number (syntax rule {IV.B.1} 9). If ANUM is a valid number, return EFLAG set to 0. Otherwise, set RELCON to 0.0, set EFLAG to 1, and print error message.

REPTGL(LSC)

subroutine

Report on the calculation of window optical coefficients. This report is initiated by CONS (2.1.3). The report is in two formats: one for detailed optical calculations and the other if a shading coefficient was used (LSC true).

REPTRF

subroutine

Report on the calculation of conduction transfer functions. This report is initiated by CONS (2.1.3). Also report surface properties.

RESPNS

subroutine

Direct the calculation of conduction transfer functions for multi-layered slabs.

RFCOMP

subroutine

Compute conduction transfer functions for multi-layered slab from the roots and residues.

RPT

subroutine

Evaluate the subkeys of RPT (1.2). Data is stored in the RFLAGS array.

RSBF(I,COSINC,WL)

real function

Compute reflectance of an interior shading device. This returns the value of RSO which was computed from user input REF (2.4.12). This routine is a program stub to allow computation of reflectance from polarization (I), angle (COSINC), and wavelength (WL) when data for such a calculation exists.

SATPTX(T)

real function

Compute the saturation pressure of water at temperature (T) by the detailed ASHRAE correlation (B.2). This subroutine is not called by TARP. It is used with PSYCH to test the psychrometric package.

SATUPT(T)

real function

Compute the saturation pressure of water at temperature (T) (B.2.1). Check for $-70 < T < 100$.

SATUTP(P)

real function

Compute the saturation temperature of water at pressure (P) (B.2.1). Check for P in the range corresponding to $-70 < T < 100$.

SEARCH

subroutine

Determine upper and lower bounds within which a root must exist. Call ILLINI to converge to root. Trigonometric identities are used (with APPROX) to evaluate AS and BS as PT is incremented. The search for roots of BS is helped by the fact that roots of BS must lie between roots of AS.

SETUPV

subroutine

Compute vertices of polygon. Vertices of rectangular and non-rectangular base surfaces are evaluated in the global coordinate system by equations (E.1.4). Rectangular subsurfaces have vertices computed in the base surface coordinate system. Subsurface azimuth and tilt angles are computed from the base surface angles.

SHD

subroutine

Evaluate the subkeys of SHD (4.15). Data is output in the SRFIS common block.

SIM subroutine

Evaluate the subkeys of SIM (3.1). Data is stored in the RUNCTL common block and output as one of the last steps of input processor operation.

SLR program

SLR stands for "simplified language reader". This is the root program of the input processor. It initializes program variables and opens files, directs the processing of input sections, prints final reports and closes files. The variable SEQ is used to insure that sections are not used out of sequence.

SKYTF(TA,TD,N) real function

Compute sky temperature from dry bulb (TA) and dew point (TD) temperatures and tenths cloud cover (N - integer) (B.3.1 through B.3.4)

SPCTRM subroutine

Use the detailed optical algorithms to compute the window optical properties. This routine includes a loop to integrate the optical properties over wavelength. The loop is executed for only one average wavelength. This was found to give satisfactory results for typical window materials.

SRF subroutine

Evaluate the subkeys of SRF (4.13). Data is output in the SRFIS, HTSIL, and HTSISL common blocks. The subkey names (in KEYS) are sequenced according to frequency of occurrence to speed the INDEX operation in SUBKEY. The large number of options in the SRF description make this the most complex input subroutine. There are several error messages relating to syntax requirements. Then the sky and ground view factors are computed by (E.5.2a) and (E.5.2b), unless the user chose to provide his own values by (4.13.7) and (4.13.8). The surface area (gross area for base surfaces) is computed from (E.4.1). The conductive and radiative properties of the surfaces are read from unit 5. If the surface is an interzone partition (IZP), and attempt is made to match it to previously defined IZP's. An IZP must be described in two zones. RNOS=7 (1.2.1) reports on this matching process. The surface geometric data (primarily coordinates of vertices) is computed. Values are stored in the BASES common block for the geometric description of subsurfaces.

SUBKEY(KEYS,LKEYS,NKEYS,LOC)

subroutine

This subroutine evaluates the subkey name (syntax element [IV>B>1] 4). The subkey name is always the first word in ALIST. KEYS is a single string of all subkey names, each no more than LKEYS characters long. The number of names in KEYS is NKEYS. LOC is the word number location of the subkey name in KEYS. The INDEX function is used in determining LOC. If the name is not found, an error message is printed. All valid subkey names are optionally (DEM - 1.1.3) printed.

SUDDEN

subroutine

This routine fills a single day of weather data in common block ENV DAT from the user's design day description (DDY - 1.6). Calendar values are computed. A dew point temperature (TD) for the day is computed. It is used in computing the hourly wet bulb temperatures, humidity ratios, and sky temperatures. Solar intensities are computed.

SUN2(DAYYR,A,B,C,AVSC)

subroutine

Compute the ASHRAE A, B, and C values from the day-of-year (DAYYR). These are computed from truncated Fourier series computed from data in ASHRAE 1981 Fundamentals, page 27.2.

SUN5(HOUR)

subroutine

Compute the solar direction cosines at standard time HOUR.

SURFIN(ZAVG,ZTOP)

subroutine

Compute coordinates of surface vertices. Determine average and maximum height of surface from ground.

TSBF(I,COSINC,WL)

real function

Compute transmittance of an interior shading device. This returns the value of TSO which was computed from user input TRNS (2.4.9) and REF (2.4.12). This routine is a program stub to allow computation of transmittance from polarization (I), angle (COSINC), and wavelength (WL) when data for such a calculation exists.

VALID(KEYS,LKEYS,NKEYS,LEVEL)

subroutine

List valid input names. LEVEL (equals 1, 2, or 3) determines whether section, key, or subkey names are being listed. The names are all in the single string KEYS. The number of names is NKEYS. Each is LKEYS characters long.

VENT

subroutine

Evaluate the subkeys of VENT (4.6). Data is output in the CGSIL common block.

WDWPOL

subroutine

This routine directs the calculation of the polynomial coefficients (D.1.7a and b) describing the optical properties of the window.

WS

subroutine

Evaluate the subkeys of WS (2.3). Data is output in the local array PTR and the optional report is on unit 22. The day schedule pointers can be filled from a single weekday pointer.

WTAP

subroutine

Evaluate the subkeys of WTAP (1.5). Get weather from the BLAST weather file unless SYNTAX (1.1.2) or OLDW (1.1.6) are in effect.

WXREF(A,I)

subroutine

Write cross reference data consisting of the array name (A) and the location (I) in that array. WXREF is initiated by XREF (1.1.5). It relates the input keys to the arrays reported by DUMPIN in the loads calculator. DUMPIN is caused by RNOS=8 (1.2.1).

ZERO(ARRAY,LEN)

subroutine

Set ARRAY (length LEN) of real numbers to 0.

ZERORE

subroutine

ZERORE calculates the residues related to the double pole at zero.

ZONE

subroutine

Evaluate keys of ZONE (section 4.). Insure sequence of KEY input. Data is output in the ZONISL common block. Key names (in KEYS) are approximately in the order of frequency of occurrence to speed execution of the INDEX function. This is the root subroutine of the zone segment.

This diagram (continued over several pages) shows the general relationship of the input processor subroutines to each other. A subroutine calls other subroutines which are to the right and below it on the diagram. Multiple calls to the same subroutine are not shown, only the first. Circled letters are continuation points for often used groups of subroutines and for large groups of subroutines. Not all subroutines and functions are included. The intrinsic FORTRAN 77 routines have been left out. Several simple utility routines which are called from many places are not always shown. These include: ERROR, INTCON, IZERO, LOCLIB, MODY, PAGE, RELCON, WXREF, and ZERO.

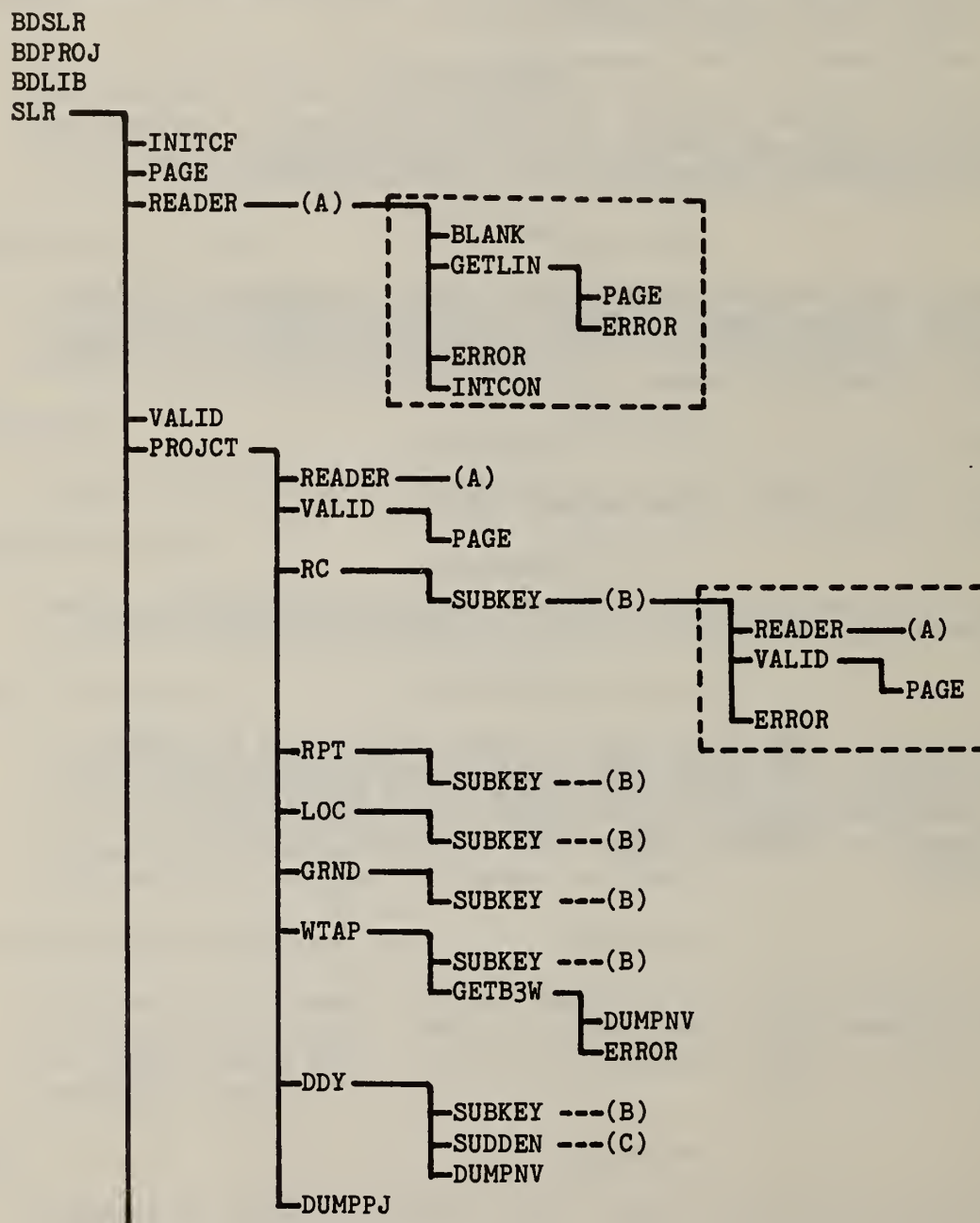


Figure VI.A.1 Tree structure of input processor program

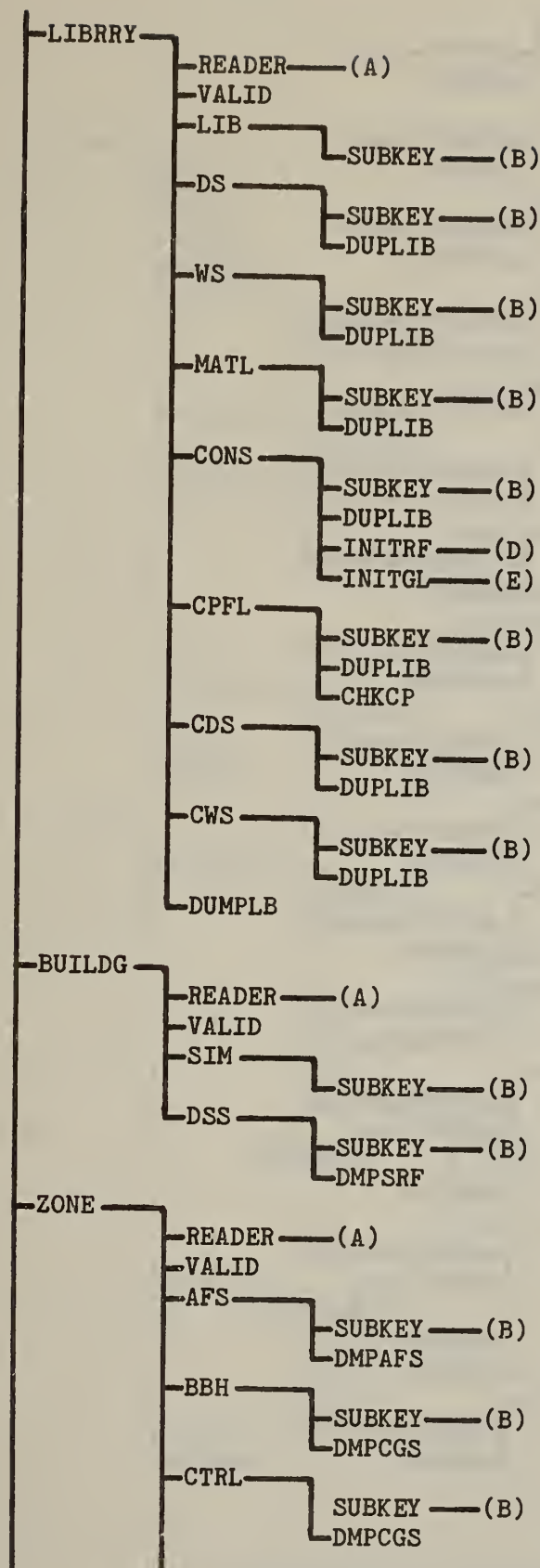


Figure VI.A.1 (continued)

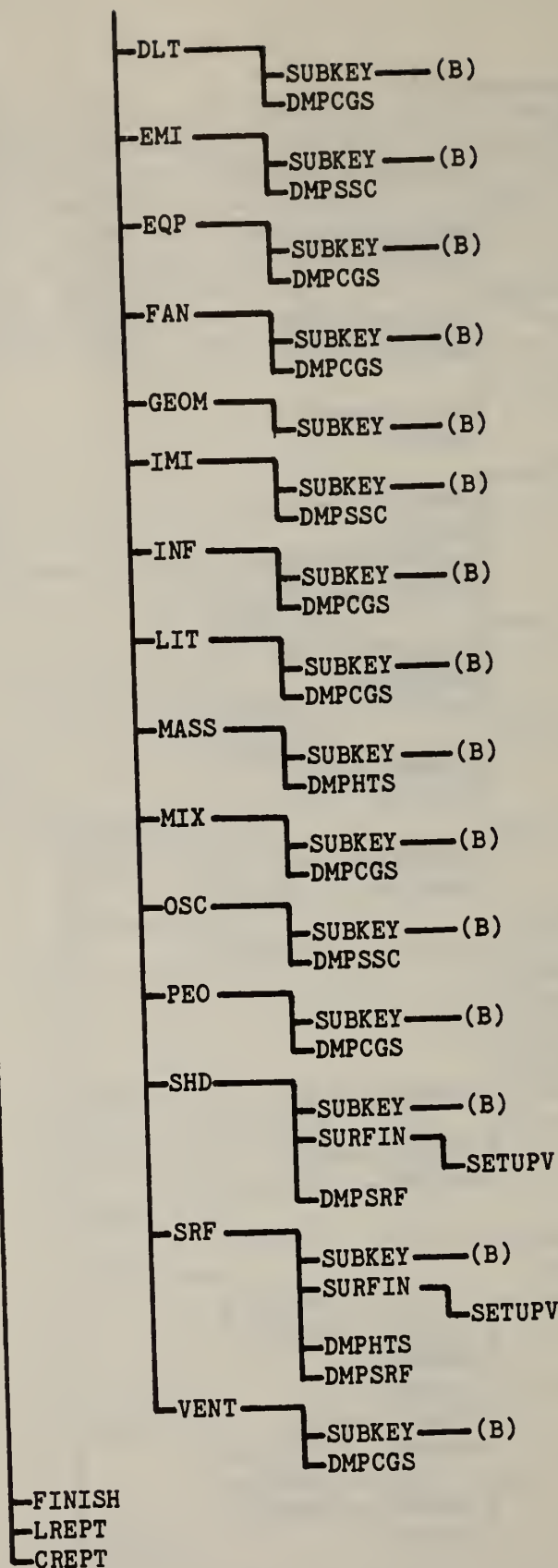


Figure VI.A.1 (continued)

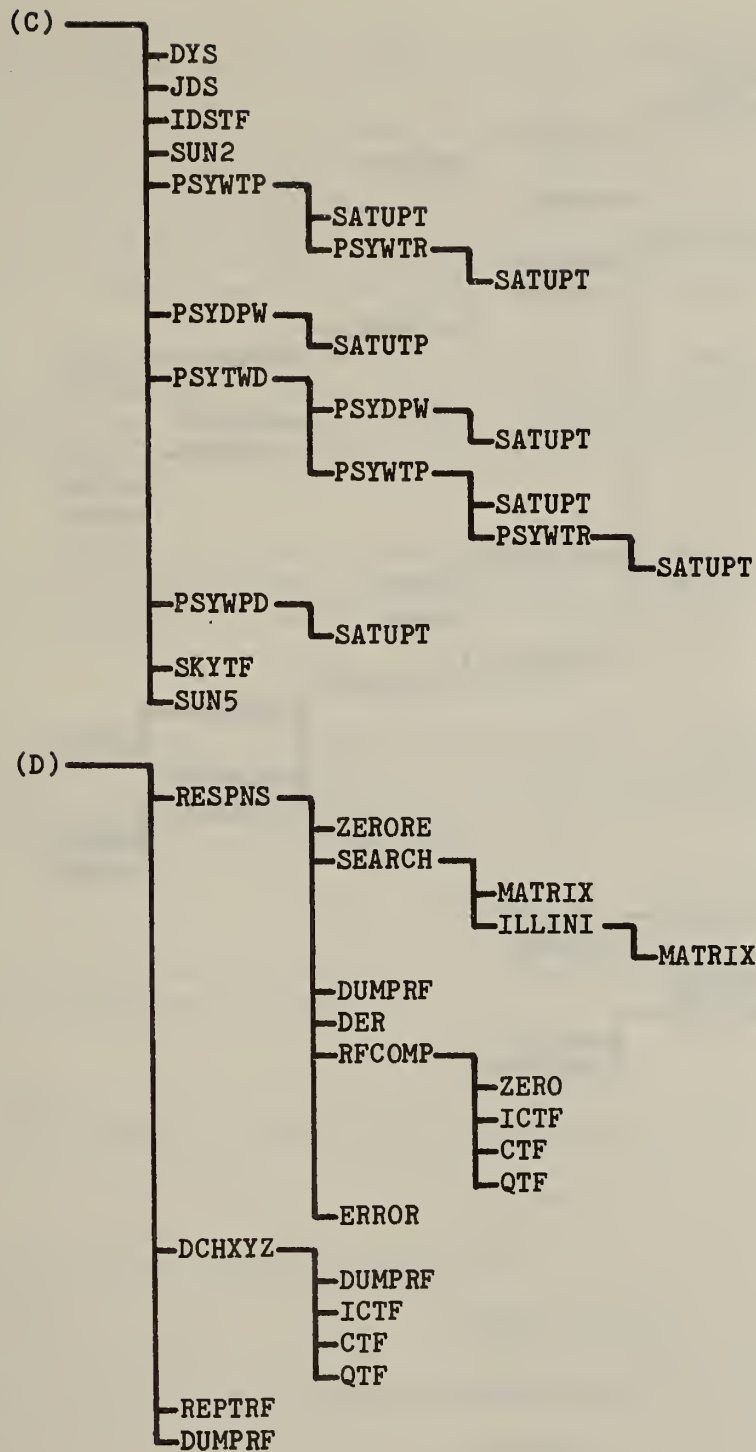


Figure VI.A.1 (continued)

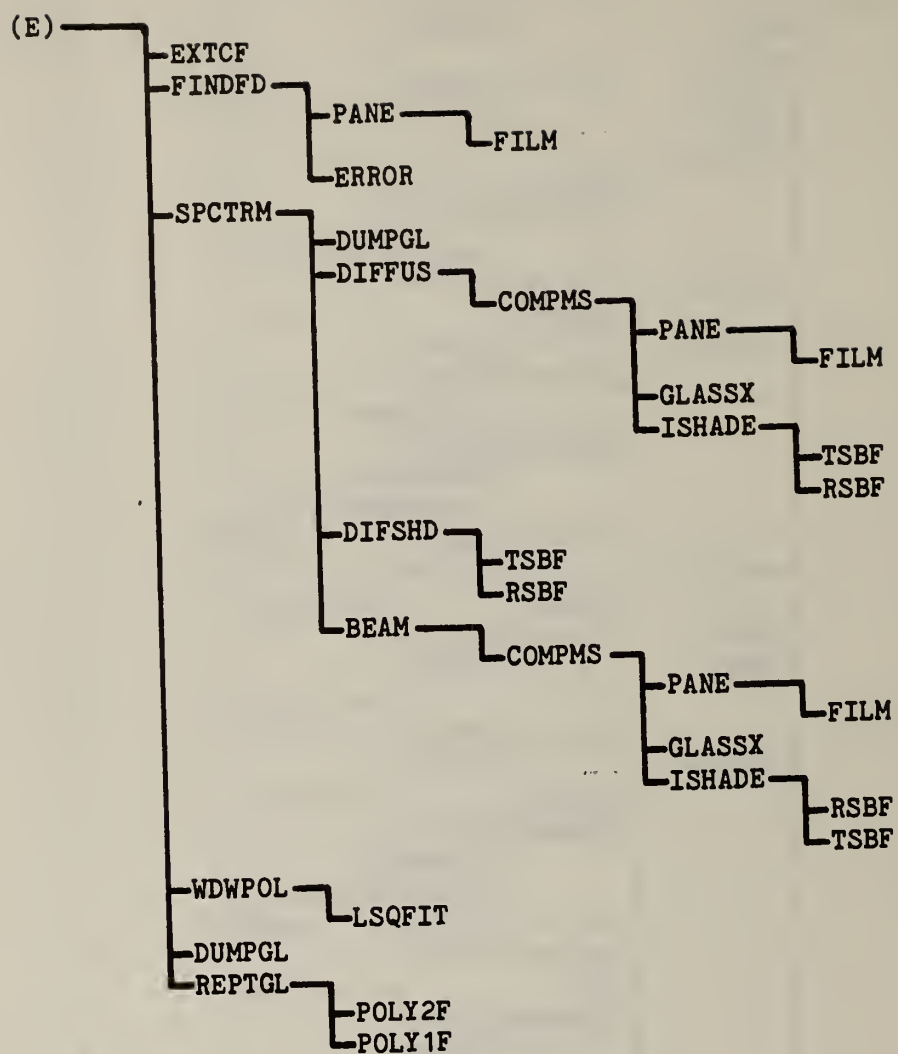


Figure VI.A.1 (concluded)

VI.B LOADS CALCULATOR

The loads calculator (LC) subprogram of TARP computes the zone loads based on the algorithms in chapter III, primarily sections E through L. It is divided into three sections. The first reads the SINPFL created by the IP and fills the LC arrays. It checks for sufficient array space and performs some checks and calculations which require that the entire building description be present in the arrays. The second section uses the geometric and optical descriptions of the building surfaces to compute solar gain factors for various periods of the year. The third section computes the zone loads by simultaneous, hour-by-hour heat balances.

The three segment structure of the LC is used to name many of the common blocks. For example, common block HTSISL is composed of variables dimensioned MAXHTS and is used in the Input, Shadowing, and Loads segments. Common block ZONL has variables dimensioned MAXZON and is used in only the Loads segment.

A short description of each of the 90 loads calculator subroutines is given below. After the descriptions is a diagram (figure VI.B.1) showing the general relationship of the LC routines and the segment structure.

AIRMVO subroutine

Compute air movements for the simple algorithms: infiltration (INF - 4.5 - K.2), two zone mixing (MIX - 4.7 - K.3), and whole house fan (FAN - 4.8 - K.4). The mixing and fan models may not be used when other ventilation (VENT - 4.6) is possible.

AIRMV1 subroutine

Compute infiltration and interzone air flows using the detailed air movement algorithms in III.G.

BDMRL block data

Set initial values for loads calculator program.

BDSIM block data

Set initial values for loads simulation.

BETWEEN(N1,N0,N2) logical function

Determine if cyclic date N1 lies between dates N0 and N2 (B.1.6).

CALOAD subroutine

Calculate values for the building loads report including system status hours, zone loads, zone peaks, building loads, and building peak values.

CHACS

subroutine

Set up the control points and coefficients of the system performance (K.1) and ventilation models (K.3).

CHKBKS(NRS,NBS)

subroutine

Check that a convex zone has been defined. No vertex of surface number NBS may lie in front of surface number NRS.

CHKGSS(NRS,NSS,ZMIN,NOSHAD)

subroutine

Determine if surface number NSS can possibly shade surface NRS. If it can, set NOSHAD false. NSS cannot shade NRS if any of the following conditions are true:

- (1) No point of NSS is above the lowest point (height ZMIN) of NRS.
- (2) NSS is horizontal and faces up.
- (3) NSS is entirely behind NRS.
- (4) NRS is entirely behind NSS.

CHKSBS

subroutine

Check that a subsurface is completely enclosed by its base surface. This routine uses the shadow overlap technique.

CISAF

subroutine

Compute the fraction absorbed by each surface of the total beam solar energy transmitted into the zone. This is for the simple solar distribution which assumes all beam solar gains are incident on the floors of the zone. The fraction absorbed is proportional to the solar absorptance of each floor.

CIVAF

subroutine

Compute the distribution of diffuse short wavelength radiation on all surfaces. Each surface absorbs a fraction of the total diffuse energy in the zone in proportion to its area and solar absorptance with an allowance for loss through transparent surfaces (F.2.1).

CLIP

subroutine

'Clip' the shadowing surface polygon so that none of it lies below the plane of the shadow receiving surface (E.2). This prevents the casting of false shadows.

CROSS(A,B,C)

subroutine

Compute C as the cross product of A and B. All are three element vectors.

CTTRANS(NS,NR)

subroutine

Transform the coordinates of the vertices of surface NS from the global coordinate system to the surface coordinate system relative to surface NR (E.1.5).

DAILY

subroutine

Perform all operations which can be done once per day. Read the weather data and set date values. Set the solar gains file group number. Check external movable insulation and set pointers if the date is in effect. Set the schedule and control pointers according to the date. Set the monthly report flags.

DOT(A,B)

real function

Compute the dot product of A and B which are each vectors of 3 elements.

DUMPAF

subroutine

Dump air flow values (RNOS=23 - 1.2.1).

DUMPEH

subroutine

Dump values in the environment file header (RNOS=8 - 1.2.1).

DUMPHW

subroutine

Dump weather values for the hour (RNOS=21 - 1.2.1).

DUMPIN

subroutine

Dump all values read from the simulation input file (RNOS=8 - 1.2.1).

DUMQPB

subroutine

Dump results of the zone loads calculations (RNOS=23 - 1.2.1).

DUMPSC

subroutine

Report shadowing combinations (RNOS=14 - 1.2.1).

DUMPSG

subroutine

Dump solar gain values (RNOS=22 - 1.2.1).

DUMPST

subroutine

Dump Surface temperatures and other surface related values (RNOS=23 - 1.2.1).

GAUSSY(A,B,X,N,MAX)

subroutine

Solve a system of simultaneous linear algebraic equations ($A * X = B$) by Gauss elimination. There are no safety check or pivoting in this routine: it will not fail gracefully for an invalid set of equations. It is used in the Newton iteration for pressure where the A matrix is diagonally dominant and known to produce valid equations.

HBAIR(CNVG)

subroutine

Compute the zone air temperatures for normal control (K.1.4) or ventilation control (K.3). Check heat balance convergence and set CNVG false if it has not been achieved.

HBOUT

subroutine

Compute surface outside temperatures for building envelope surfaces. Use the algorithms in I.4.

HBSRF

subroutine

Compute surface inside temperatures according to algorithms in J.3, J.4, and J.5.

HTRANS(I,NS,NV)

subroutine

Convert Cartesian coordinates to homogeneous coordinates (E.3) and compute the area (E.4.1) of the figure.

IBLRPT

subroutine

Initialize the building loads report variables.

IMRTNW

subroutine

Initialize the mean radiant temperature network algorithm. Compute the MRT view factors (H.2.2) and the constant part of the radiative conductance (H.2.3).

IMVINS(I,N)

subroutine

Determine presence of inside movable insulation for heat transfer surface I in zone N. If present, set UM(I) to the insulation U-values. Otherwise, set UM(I) to zero.

INCLOS(N1,NV1,N2,NV2,NV3,NIN)

subroutine

Determine which vertices of HC figure N1 lie within figure N2. N1 has NV1 vertices, and N2 has NV2 vertices. NIN is the number of enclosed vertices. NV3 is a running count of the number of vertices in the overlap of N1 and N2. The algorithm is described in E.4. The coordinates of the inclosed vertices are stored in XTEMP and YTEMP.

INITBL

subroutine

Direct the set-up of the simulation data. This is the root routine in the initialization segment. The segmentation is helped by temporary storage of data on units 4 and 5. The report of array limits is the first action. It will occur even if there is no SINPFL or ENVTFI attached. Next, those files are opened and the environment header is read. Then the SINPFL is read [READER] and the required array space reported. Some calculations are made that require data simultaneously for all zones and surfaces [SETIZP, CISAF, and CIVAF]. Dumps [DUMPEH, DUMPIN] (RNOS=8, 1.2.1) and reports [REPTZD] (RNOS=9, 1.2.1) are written. Inter-segment scratch files 4 and 5 are written.

INITSG

subroutine

Direct the calculation of the solar gains multipliers. This is the root routine of the solar gains segment. The segmentation is helped by the temporary storage of data on unit 5. Determine shadowing combinations [SGCOMB]. Read the environment file to determine solar position and days to be simulated.

INITTH

subroutine

Initialize temperatures and temperature/flux histories.

INITZP

subroutine

Initialize values for computing zone pressures. In particular, set the ZZ(0) and PZ(0) values (for ambient air) to zero. Set system flows to zero. Set wind pressures to zero (needed to allow inclusion of PW term in the equation for internal surfaces).

INTCPT

subroutine

Determine all intercepts between the sides of figure NS2 and the sides of figure NS1 (E.3.4 and E.4).

IZERO(ARRAY,LEN)

subroutine

Set ARRAY (length LEN) of integers to 0.

JDS(JFLAG,JD,YR,MO,DM)

subroutine

If JFLAG = 1, compute the Julian date (JD) from the year (YR), month (MO), and day-of-month (DM) (B.1.2). Otherwise, compute YR, MO, and DM from YR (B.1.3).

LOCRA(N)(LIST,LEN,ITEM)

integer function

Determine the location of ITEM in a LEN long array (LIST) of unordered words. A linear search is used. An unsuccessful search returns the value zero.

MRL(OUTPUT,SINPFL,ENVTFLL)

program

Multi-room loads program. This is the main (or root) program of the loads calculator. It calls the three segments of the loads calculation.

MRTNET

subroutine

Compute the zone mean radiant temperatures for the second and subsequent heat balance iterations. Use the simple (H.2.3) or the detailed (H.2.4) algorithm. This routine includes equations to improve heat balance convergence.

MRTNT1

subroutine

Compute the zone mean radiant temperatures for the first heat balance iteration of the hour. Use the simple (H.2.3) or the detailed (H.2.4) algorithm. This routine includes equations to improve convergence of the MRT on the first iteration. Development of those equations is not complete.

MULTOL(NNN,LOCO,NRFIGS)

subroutine

Determine the overlaps of figure NNN with previous figures stored in locations LOCO+1 through LOCO+NRFIGS of the HC arrays.

OCNVCO(I,HM,OABS,TO,HO,HS,HG)

subroutine

Evaluate the heat exchange coefficients HA (=HO), HS, and HG for heat transfer surface number I. Input also includes the U-value of movable insulation, if present, the solar absorptance of the surface/movable insulation, and the most recently computed surface outside temperature TO. Use the algorithms in (I.2). The surface temperature of movable insulation is estimated from (I.3.8) with HO as input computed from the simple algorithm.

OMVINS(I,OABS)

subroutine

Evaluate external movable insulation for heat transfer surface number I. If it is present, return its solar absorptance in OABS and set UM(I). Otherwise, set UM(I) to zero.

ORDER(NS3,NV3)

subroutine

Sort the unordered vertices found by enclosure [INCLOS] and intercept [INTCPT] into clockwise sequence for use by subsequent overlap calculations. Results are placed in location NS3 in the HC arrays.

OVLAP

subroutine

Use homogeneous coordinate techniques (E.4) to compute the overlap between two convex polygons.

PAGE(IACT,NEED)

subroutine

Write output report page heading. See PAGE description in the list of IP subroutines.

POLY1F(X,A,N)

real function

Evaluate simple polynomial expression (D.1.7a):

$$P = A(1) + A(2)*X + A(3)*X^2 + \dots + A(N)*X^{N-1}$$

POLY2F(X,A,N)

real function

Evaluate simple polynomial expression (D.1.7b):

$$P = A(1)*X + A(2)*X^2 + \dots + A(N)*X^N$$

QINSRC

subroutine

Compute (or set up parameters and pointers) for scheduled internal loads. First initialize the loads arrays. Then process every element in the CGS arrays (that is not off for the day) according to type (CGSTYP).

QSDIST

subroutine

Distribute short wavelength radiant gains (solar and lights) on the inside surfaces of the zones. This includes a single pass of light through transparent interzone partitions and calculation of the light converted to instantaneous convective gain on internal shades. Determine if the radiant gain should be placed on movable insulation instead of the surface. Include the transmission of light through windows ut of the zone and to the environment.

QSUN

subroutine

Determine solar gains. Use the solar gains multipliers and the solar radiation intensities to determine the diffuse solar gains in the zones, the solar gains on outside surfaces, and the beam solar gains on inside surfaces. Also evaluate placement of movable insulation for the hour [IMVINS and OMVINS].

READIN

subroutine

Read the simulation input file (SINPFL) and determine the array space used. Data which was prepared in single element arrays in the IP is read into multiple element arrays. The reading is directed by two-element records that tell which arrays will be filled when the next record is read. The unformatted read statements must match the IP write statements. Note that each data read is protected to prevent array overflow. Also note that a simulation control information (created in FINISH) must be the last record read. Otherwise, an end-of-file is encountered which terminates the run.

REPTBL	subroutine
Report building loads (a default action).	
REPTSM(KEY)	subroutine
Report simulation values like numbers of iterations and execution time. Time is determined by the non-ANSI function SECOND. This function can be removed without otherwise effecting the program.	
REPTZD	subroutine
Report a description of the zone (RNOS=9 - 1.2.1).	
RPTASU(NR,MAX,NAME,LIMIT)	subroutine
Report array space utilization. For PARAMETERized arrays, print a message giving the number (NR) of elements utilized and the short parameter name (NAME). If NR is greater than the size (MAX) of the arrays, print a string of stars to highlight the message and set LIMIT true.	
SETIZP	subroutine
Set interzone pointers for interzone partitions, MIX and FAN operations, and interzone air flow openings. Unmatched items cause run termination.	
SGACTN	subroutine
Determine which groups of days are used for shadowing calculations. This is based on the shadowing group dates (Table IV.G.1) and the dates of any shadowing surface or movable insulation actions which change the building shadowing configuration. The angles (declination and equation of time) from which solar position is calculated are determined by averaging the values for all days in the period.	
SGBEAM	subroutine
Direct the calculation of solar gains multipliers for a day. For each hour, compute the angle of incidence of the sun's rays on every surface (E.2.2); compute the solar multipliers [SHADOW]; store the results on unit 3 for later heat balance calculations.	
SGCOMB	subroutine
Determine which surfaces can shade each other. This is constant for the entire simulation and can, therefore, be used to avoid recomputing such data at every hour. Data is stored in the SHDCMB array and is used to direct the calculation sequence of the SHADOW subroutine. Shadowing combinations are computed for heat transfer, exterior, base surfaces. All surfaces which can shade the base surface are determined [CHKGSS]. All heat transfer subsurfaces are determined [CHKSBS]. For	

the detailed solar distribution algorithm, all inside surfaces which might receive beam sunlight are determined [CHKBKS]. Complex building configurations which cause SHDCMB to overflow are handled by reducing the level of shadowing detail, if possible.

SHADOW(IHOUR)

subroutine

Compute the sunlit areas and solar gains multipliers for all building envelope surfaces at time IHOUR. From the shadow combinations array, determine the number of shadowing surfaces (NGSS), inside (back) surfaces (NBKS), and heat transfer subsurfaces (NSBS). If the surface faces away from the sun, its sunlit area (and all subsurfaces) must be zero. If it faces the sun and there are no shadowing surfaces, it must be totally sunlit. Otherwise, compute the shadow patterns on the surface [SHDGSS]. For window subsurfaces and the detailed solar distribution call SHDBKS. Then process the subsurfaces [SHDSBS] to compute their sunlit areas and solar gains multipliers and to determine how they modify the gross sunlit area of the base surface. Finally, compute the solar gain multiplier of the base surface.

SHDBKS(NGRS)

subroutine

Project the zone inside surfaces along the sun's rays to the plane of the current general shadow receiving surface. This is done for the detailed internal solar distribution (3.1.2) if there are windows on the base surface and if the sun might shine through the window onto the inside surface. This is not possible if the inside surface faces the sun. The projected figure of the inside surface is reduced to fit within the base surface by the overlap algorithm (E.4) [OVLAP].

SHDGSS(NGRS)

subroutine

Compute the shadow figures on surface (base surface - 4.13.2) number NGRS. If there are no shadowing surfaces, the surface must be fully sunlit. Otherwise, determine the shadows from all shadowing surfaces. If the shadowing surface is sunlit, it cannot be casting a shadow (E.2) so skip it. Also skip if indicated by shadowing surface dates. Transform and clip the coordinates of the shadowing surface to the receiving surface coordinate system (E.2). Determine the overlap of the shadow on the surface (E.4). Also determine how it overlaps any previous shadows. Add (signed) shaded areas to compute the gross sunlit area of the base surface. The effects of subsurfaces is not yet computed.

SHDINT(L)

subroutine

Determine the distribution of solar gains from a single window of optical type L (index to optical coefficients). Compute multipliers for zone diffuse gains. Compute multipliers for beam gains using detailed or simple internal solar distributions. The detailed distribution involves overlapping the window sunlit pattern with the

projections of the internal surfaces along the sun's rays to the plane of the base surface and computing the sunlit area of each internal surface. If the internal surface is transparent, its diffuse transmittance is used to pass sunlight into the adjacent zone. The simple distribution puts the sunlight on the floor(s) of the zone according to ISABSF [CISAF]. In either case, that portion of the sunlight which is not directly absorbed by the internal surface becomes a diffuse gain for the entire zone.

SHDRVL

subroutine

Evaluate the shadowing effect of a subsurface setback (4.13.6). The shadow from the setback reduces the potential sunlit area of the subsurface. This potential area is still rectangular. It is overlapped with the shadow figures already known to lie within the subsurface opening [SHDSBS] to compute the actual sunlit area.

SHDSBS(IHOUR)

subroutine

Evaluate the sunlit areas of the subsurfaces (windows, doors). The shadow patterns have already been accurately determined on the base surface and stored in the homogeneous coordinate arrays [SHDGSS]. The subsurfaces are evaluated one at a time. Each subsurface figure is overlapped with the shadow figures. This determines a sunlit area which must be removed from the gross sunlit area of the base surface. Check for movable insulation [SMVINS] and if it applies skip most of the following calculations. Evaluate the shadowing effect of a setback [REVEAL]. If the surface is transparent, compute its optical properties and determine the windows contribution to the distribution of sunlight in the zone [SHDINT]. Finally, compute the solar multipliers for the subsurface.

SIMBLD

subroutine

Simulate the building thermal performance. This is the root routine of the loads segment. The segmentation is helped by temporary storage of data on unit 4. There are several initializations [IMRTNW, REPTSM(1), and IBLRPT]. The largest initialization requires several days simulation [SIMDAY] to remove the transients in the temperature histories. This initialization is terminated in accordance with the hourly heat balance convergence criteria. Then the actual simulation [SIMDAY] is done for the number of days required. A summary report is printed [REPTBL].

SIMDAY

subroutine

Do the simultaneous multizone heat balance calculations for one day. This involves an initialization of values which are constant for the day [DAILY] followed by a loop of heat balance calculations for 24 (standard time) hours. The loop involves setting up the constant values for the hour (weather data, solar gains [QSUN], scheduled loads

[QINSRC], control profiles [CHACS], distribution of short wavelength radiation [QSDIST]), doing the first iteration of the multizone heat balance (compute variable coefficients [VARTMP], air movements [AIRMV0 or AIRMV1], surface outside heat balances [HBOUT], mean radiant temperatures [MRTNT1], surface inside heat balances [HBSRF], the zone air heat balances [HBAIR]), do subsequent iterations to convergence, summarize the hour's loads data [CALOAD], and prepare for the next hour [UTHRMH]. Various data dumps are available as the calculations proceed.

SMVINS(K,IHOUR,OABS)

subroutine

Evaluate exterior movable insulation (EMI). K is the pointer stored in SSCPTR(heat transfer surface number). It points to data about the EMI in the ISSC/RSSC arrays. Time (IHOUR), environmental conditions, and the type of control will determine if the EMI is applied or if it is not. If it is not, OABS is set to zero. If it is applied, OABS is set to the solar absorptance of the EMI.

SOLVZP

subroutine

Solve the detailed air flow equations for the zone pressures. On the first iteration of the hour approximate the zone pressures (PZ) by solving a linear set of equations (flow exponents set to one). This gives a reasonable set of starting values for PZ. Then use a modified Newton's method to solve the simultaneous non-linear algebraic equations (G.3.5, G.4.1a to c). This method always produces a diagonally dominant matrix which can be solved by GAUSSY, a simplified Gauss elimination routine.

STATUS(UNIT)

subroutine

Print the status of unit number UNIT as determined by the FORTRAN INQUIRE function. This routine is used for program debugging purposes only.

SUN3(DAYYR,SINDEC,EQTIM)

subroutine

Compute the sine of the solar declination angle (SINDEC) and the equation of time value (EQTIM) for a given day-of-year (DAYYR).

SUN4(HOUR)

subroutine

Compute the solar direction cosines for a given HOUR.

UTHRMH

subroutine

Update the surface temperature and flux history values. All histories are stored contiguously in the TFH array. New values of temperature and flux are added to the array by overwriting old values (that will not be needed next hour) of other surfaces. This causes the histories

This diagram (continued over several pages) shows the general relationship of the loads calculator subroutines to each other. A subroutine calls other subroutines which are to the right and below it on the diagram. Multiple calls to the same routine are not shown, only the first. Circled letters are continuation points for often used groups of subroutines. Not all subroutines and functions are included. The intrinsic FORTRAN 77 have been left out. The simple utility routines ERROR and PAGE which are called from many places are not always shown.

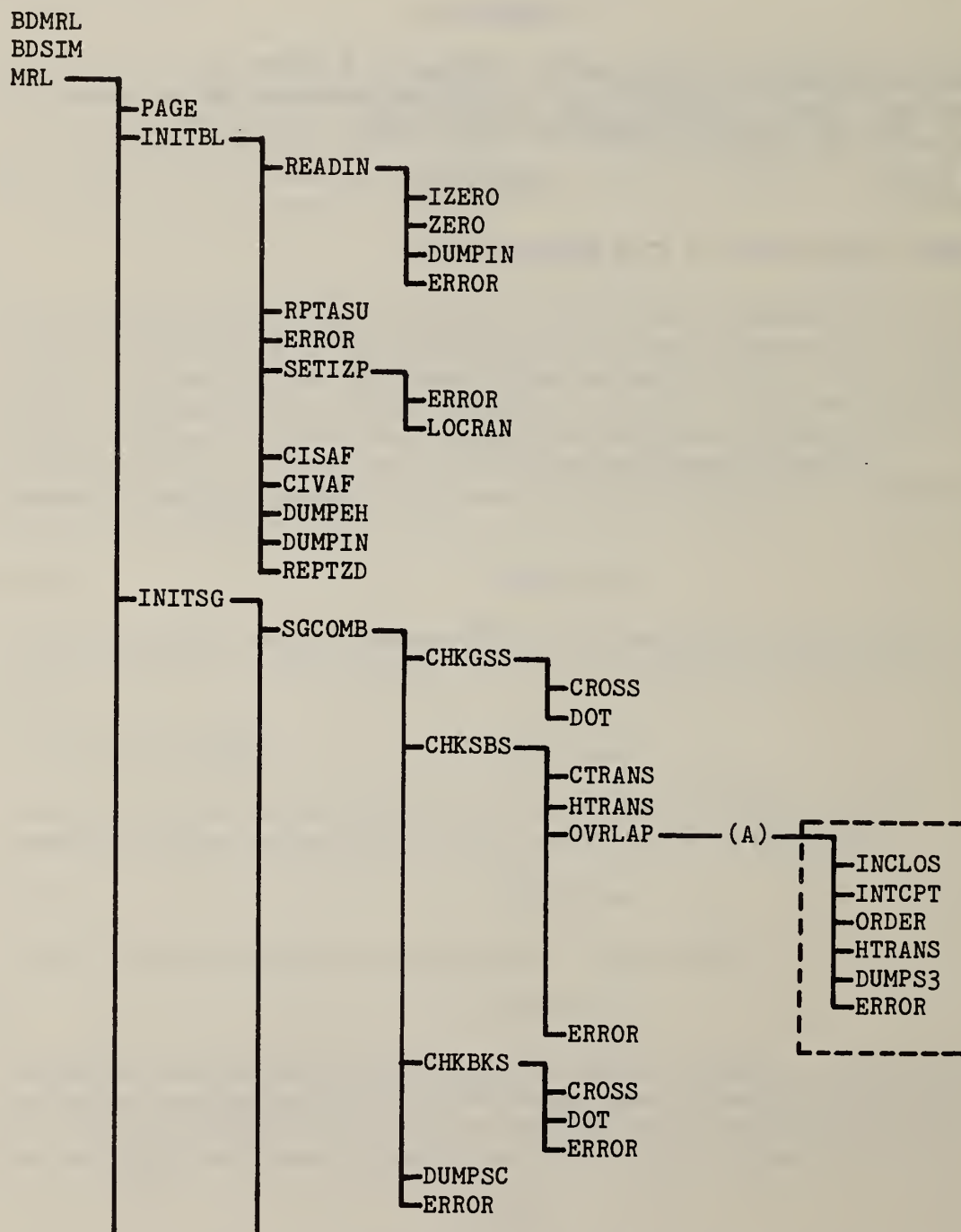


Figure VI.B.1 Tree structure of the loads calculator program

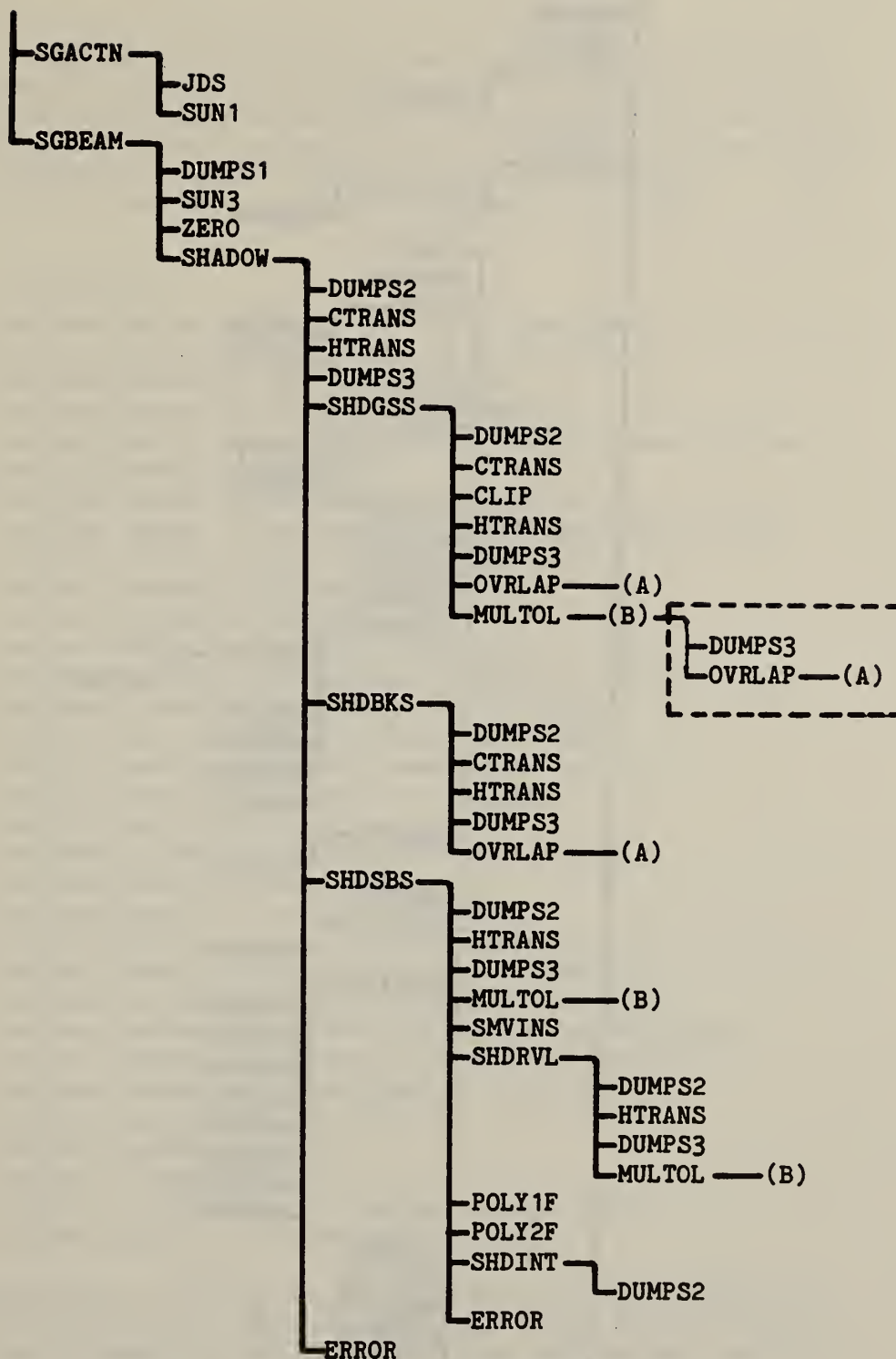


Figure VI.B.1 (continued)

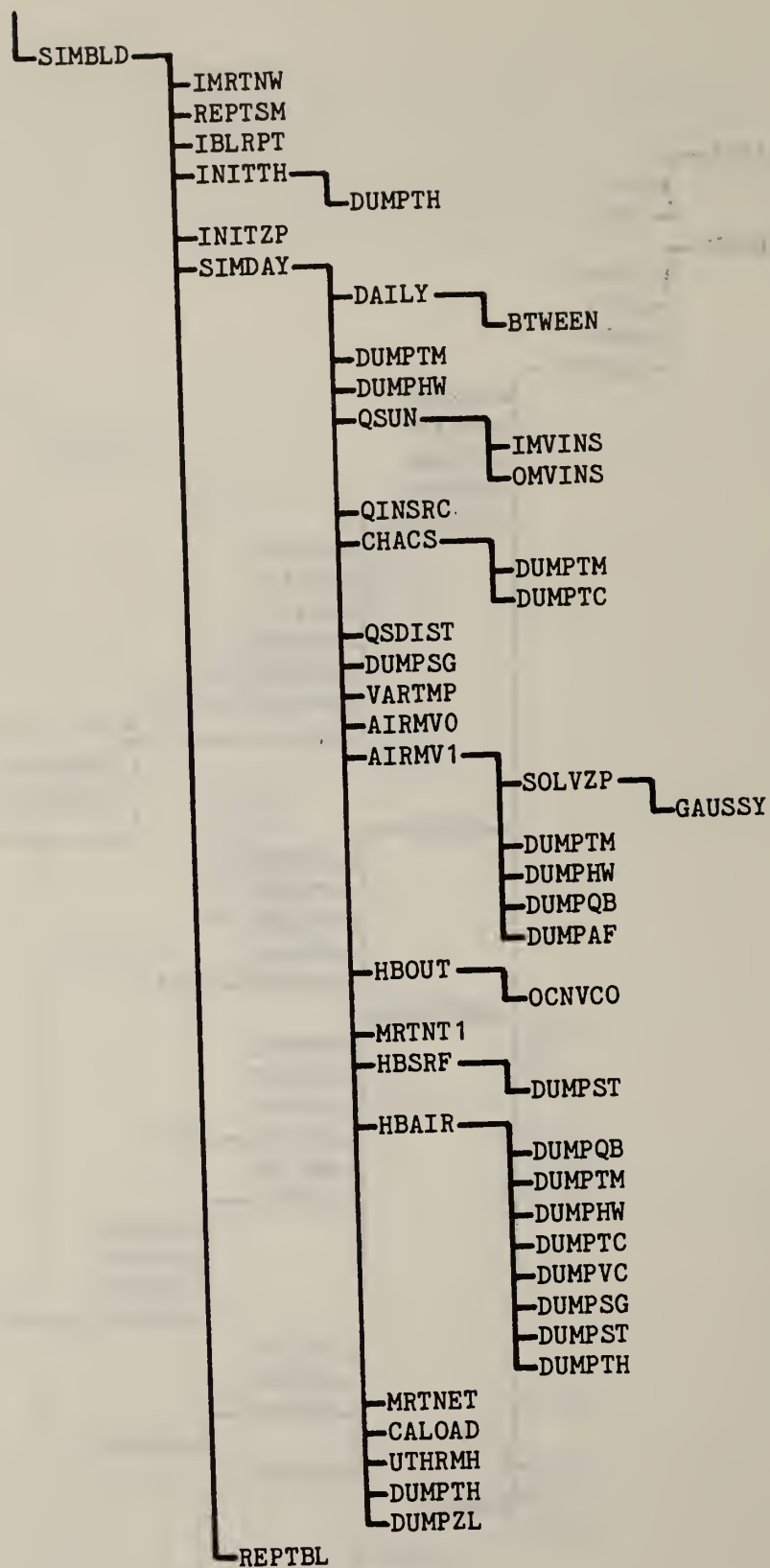


Figure VI.B.1 (concluded)

VI.C VARIABLES

PARAMETERS are extensively used to set array dimensions. This allows the same common block to describe only a single surface, schedule, etc., in the IP program and hold all surfaces, schedules, etc. in the LC. The IP computes the required dimensions necessary for the LC to simultaneously hold all descriptions. The following list describes the TARP parameters. "Short names" are those used to describe parameters in IP and LC reports.

parameter	short name	description
ALEN	-	maximum number of words decoded at one time
DESLN	-	maximum number of characters in a description
MAXAFS	AFS	maximum number of air flow openings
MAXCDS	CDS	maximum number of control day-schedules
MAXCGS	CGS	maximum number of control/general schedule descriptions
MAXCON	CON	maximum number of constructs
MAXCMB	-	maximum number of shadowing combinations
MAXCTF	CTF	maximum number of conduction transfer functions (CTF)
MAXCWS	CWS	maximum number of control week-schedules
MAXDSH	DSH	maximum number of day-scheduled
MAXENV	-	maximum number of environments
MAXGTP	GTP	maximum number of optical constructs
MAXHCS	-	maximum number of homogeneous coordinate figures
MAXHCV	-	maximum number of vertices in an HC figure
MAXHTS	HTS	maximum number of heat transfer surfaces
MAXLNM	-	maximum number of library names (entries)
MAXNL	-	maximum number of layers in a construct
MAXNRF	-	maximum number of response factors
MAXNRT	-	maximum number of roots for CTF calculation
MAXNWL	-	maximum number of wavelengths
MAXPFL	PFL	maximum number of control profiles
MAXPNT	-	maximum number of user defined points in control profile
MAXRNG	-	maximum number of control ranges (=MAXPNT+1)
MAXSSC	SSC	maximum number of special surface coefficients
MAXSRF	SRF	maximum number of surfaces (ex MASS, inc shadowing)
MAXTFH	TFH	maximum number of temperature and flux histories
MAXTMP	-	maximum number of control points (=MAXPNT+2)
MAXWSH	WSH	maximum number of week-schedules
MAXZON	ZON	maximum number of zones
RFGLN	-	number of report flags
UINLEN	-	number of characters in one user input record
WRDLEN	-	maximum number of characters in a word

Nearly all significant variables in the TARP are in common blocks. The list below describes all such variables by giving the name, common block, subprogram using the variable (IP, LC, or BOTH), type, dimensions (including parameters), and units on one line followed by a verbal description.

A	/GLAS3/	IP	real	(2,4,2)	-
	Absorptances of single panes of glass (polarization, pane number, side of incidence).				
A	/ZONL/	LC	real	(MAXZON)	C/W
	Temperature independent part of the zone heat balance equation. For example (K.1.4) and (K.4.1).				
AA	/GLAS3/	IP	real	(2,5,2)	-
	Absorptances of layers in a window system (polarization, surface number, side of incidence).				
AAB	/GLAS6/	IP	real	(16,2,5)	-
	Absorptances of a window system for beam light (angle number, polarization, surface number).				
AABW	/GLAS8/	IP	real	(16,5)	-
	Beam absorptances integrated over wavelength and polarization (angle number, surface number).				
AAD	/GLAS5/	IP	real	(2,5,2)	-
	Absorptances of a window system for diffuse light (polarization, surface number, side of incidence).				
AADW	/GLAS7/	IP	real	(5)	-
	Diffuse absorptances integrated over wavelength and polarization (surface number).				
ABI	/SHDCTL/	LC	real	-	-
	Fraction of beam solar radiation absorbed at the inside surface of a window.				
ABO	/SHDCTL/	LC	real	-	-
	Fraction of beam solar radiation absorbed at the outside surface of a window.				
ACHAR	/UINDAT/	IP	integer	-	-
	Pointer to current character in AWORD.				
ACNVG1	/RUNCTL/	IP	real	-	-
	/SIMCTL/	LC			
	Relative air flow convergence (3.1.4).				
ACNVG2	/RUNCTL/	IP	real	-	m ³ /s
	/SIMCTL/	LC			
	Absolute air flow convergence (3.1.4).				
ACNVG3	/RUNCTL/	IP	real	m ³ /s	Pa
	/SIMCTL/	LC			
	Minimum pressure across any opening (3.1.4).				

AD	/RF4/	IP	real	-	-
Upper left element of the layer derivative matrix.					
AFAREA	/AFSDAT/	IP	real	-	m ²
Air flow opening area for matching interzone openings.					
AFEXP	/AFSDAT/	IP	real	-	-
Air flow opening exponent for matching interzone openings.					
AFLOW	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Flag for detailed (1) or simple (0) air flow modeling (3.1.4).					
AFSNAM	/AFSNAM/	LC	chr*WRD	(MAXAFS)	-
Name of zone on opposite side of interzone opening.					
AFSPTR	/AFSIL/	LC	integer	(MAXAFS)	-
Number of the zone on the opposite side of the opening (0 means ambient).					
AI	/SOLFAC/	LC	real	(MAXHTS)	-
Beam solar radiation factor for the inside of a surface.					
AID	/GLASO/	BOTH	real	(MAXGTP)	-
Fraction of diffuse solar radiation absorbed at the inside surface of a window.					
AIRDEN	/AIR/	LC	real	-	kg/m ³
Density of ambient air.					
AI1	/GLAS/	BOTH	real	(5,MAXGTP)	-
Polynomial coefficients for window inside beam solar absorptance (ci in D.1.7a).					
AI2	/GLAS/	BOTH	real	(6,MAXGTP)	-
Polynomial coefficients for window inside beam solar absorptance (ci in D.1.7b).					
AL	/RF4/	IP	real	-	-
Upper left element of the layer matrix.					
ALIST	/ALIST/	IP	char*WRD	(ALEN)	-
List of words decoded from user input: a section name, key name, or subkey name and data.					
ALTD	/EFLHDR/	BOTH	real	-	m
Altitude of site (not yet used).					
AMAXIT	/RUNCTL/	IP	integer	-	-
Maximum number of air flow iterations for convergence (3.1.4).					

AN	/GLAS9/	IP	real	-	-
Index of refraction of air (=1.0).					
AO	/SOLFAC/	LC	real	(MAXHTS)	-
Beam solar radiation absorption factor for the outside of a surface.					
AOD	/GLAS0/	BOTH	real	(MAXGTP)	-
Fraction of diffuse solar radiation absorbed at the outside surface of a window.					
A01	/GLAS/	BOTH	real	(5,MAXGTP)	-
Polynomial coefficients for window outside beam solar absorptance (c_i in D.1.7a).					
A02	/GLAS/	BOTH	real	(6,MAXGTP)	-
Polynomial coefficients for window outside beam solar absorptance (c_i in D.1.7b).					
AP	/IZPDAT/	IP	real	-	m ²
Area of interzone partition.					
AREA	/HTSISL/	BOTH	real	(MAXHTS)	m ²
Area of heat transfer surface.					
AS	/RF4/	IP	real	-	-
Upper left element of the total construct matrix.					
ASD	/GLAS0/	BOTH	real	(MAXGTP)	-
Absorptance for diffuse radiation of the interior shading device.					
AS1	/GLAS/	BOTH	real	(5,MAXGTP)	-
Polynomial coefficients for beam absorptance of the interior shading device (c_i in D.1.7a).					
AS2	/GLAS/	BOTH	real	(6,MAXGTP)	-
Polynomial coefficients for beam absorptance of the interior shading device (c_i in D.1.7b).					
AT	/RF4/	IP	real	-	-
Upper left element of the total derivative matrix.					
AWORD	/UINDAT/	IP	integer	-	-
Pointer to current word in ALIST.					
AZS	/AFSDAT/	IP	real	-	m
Height of air flow opening for matching interzone openings.					
B	/ZONL/	LC	real	(MAXZON)	W
Temperature dependent part of the zone air heat balance equation. For example (K.1.4) and (K.4.1).					

BAREA	/BASES/	IP	real	-	m ²
Net area of base surface (= gross area minus subsurface areas).					
BASE	/BASES/	IP	real	-	m
Distance from surface origin to first vertex (for imaging).					
BAZM	/BASES/	IP	real	-	degrees
Azimuth angle of base surface (4.13.3).					
BBLOAD	/ZONL/	LC	real	(MAXZON)	Wh
Baseboard heating load.					
BCA	/BASES/	IP	real	-	-
Cosine of azimuth angle of base surface (4.13.3).					
BCLD	/BLDRPT/	LC	real	-	Wh
Total sensible cooling load for the building.					
BCT	/BASES/	IP	real	-	-
Cosine of tilt angle of base surface (4.13.4).					
BD	/RF4/	IP	real	-	-
Upper right element of the layer derivative matrix.					
BDRELN	/RUNCTL/	IP	real	-	degrees
Angle from true north to Y-axis of building coordinate system (3.1.1 and E.1.1).					
BETA	/RF2/	IP	real	(MAXNL)	-
Layer thickness divided by the square root of the thermal diffusivity.					
BHOC	/BASES/	IP	real	-	-
Value of HOC for the base surface.					
BHLD	/BLDRPT/	LC	real	-	Wh
Total sensible heating load for the building.					
BHTS	/BASES/	IP	integer	-	-
Heat transfer surface number of the base surface.					
BKSNR	/SHDCTL/	LC	integer	-	-
Back (inside) surface number.					
BL	/RF4/	IP	real	-	-
Upper right element of the layer matrix.					
BMNT	/BLDRPT/	LC	real	-	C
Minimum temperature of any zone in the building.					
BMXC	/BLDRPT/	LC	real	-	W
Peak cooling load for the building.					

BMXH	/BLDRPT/	LC	real	-	W
Peak heating load for the building.					
BMXT	/BLDRPT/	LC	real	-	C
Maximum temperature of any zone in the building.					
BS	/RF4/	IP	real	-	-
Upper right element of the total construct matrix.					
BSA	/BASES/	IP	real	-	-
Sine of azimuth angle of base surface (4.13.3).					
BST	/BASES/	IP	real	-	-
Sine of tilt angle of base surface (4.13.4).					
BT	/RF4/	IP	real	-	-
Upper right element of the total derivative matrix.					
BTILT	/BASES/	IP	real	-	degrees
Tilt angle of base surface (4.13.4).					
BTYP	/BASES/	IP	integer	-	-
Type number of the base surface: 1=envelope, 2=interior.					
BZS	/BASES/	IP	real	-	m
Average Z coordinate of base surface.					
BZT	/BASES/	IP	real	-	m
Maximum Z coordinate of base surface.					
C	/GLAS12/	IP	real	(6)	-
Coefficients of the window properties curve fit.					
C	/SHDCTL/	LC	real	-	-
X displacement of a shadow in the surface coordinate system (E.2.3a).					
CA	/SRFIS/	BOTH	real	(MAXSRF)	-
Cosine of surface azimuth angle (3.2.1 and 4.13.3).					
CALCS	/RUNCTL/	IP	logical	-	-
Opposite of SYNTAX.					
CAP	/TCDESC/	LC	real	(MAXPNT+1)	W
Heating/cooling capacities at the control point temperatures (Lp in K.1.1).					
CB	/SOLFAC/	LC	real	(MAXZON)	-
Beam solar radiation convection factor for the zone.					
CBI	/SHDCTL/	LC	real	-	-
Fraction of beam solar radiation convected at an interior shade.					

CC /RF/ IP real - W/m^2K
 Layer thickness * density * specific heat (= thermal capacitance).

CD /RF4/ IP real - -
 Lower left element of the layer derivative matrix.

CDATE /SIMCTL/ LC integer - -
 Cyclic date (B.1.4).

CDSH /CNTPTR/ LC integer (24,MAXCDS) -
 Control day-schedules (pointers to control profiles).

CDSNAM /LIBNMS/ LC char*WRD (MAXCDS) -
 Names of control day-schedules (2.7.1).

CDSO /LIBCTL/ IP integer - -
 Pointer to control day-schedules in L NAMES (location 0).

CFA /REPORT/ BOTH real - *
 Area conversion factor: $ft^2 * CFA(2) = m^2$

CFC /REPORT/ BOTH real - *
 Specific heat conversion factor: $Btu/lbF * CFC(2) = kJ/kgK$

CFD /REPORT/ BOTH real - *
 Density conversion factor: $lb/ft^3 * CFD(2) = kg/m^3$

CFE /REPORT/ BOTH real - *
 Energy conversion factor: $Btu * CFE(2) = Wh$

CFH /REPORT/ BOTH real - *
 Enthalpy conversion factor: $Btu/lb * CFH(2) = kJ/kg$

CFK /REPORT/ BOTH real - *
 Conductivity conversion factor: $Btu/hrftF * CFK(2) = W/mK$

CFL /REPORT/ BOTH real - *
 Length conversion factor: $ft * CFL(2) = m$

CFM /REPORT/ BOTH real - *
 Mass conversion factor: $lb * CFM(2) = kg$

CFMF /REPORT/ BOTH real - *
 Mass flow conversion factor: $lb/hr * CFMF(2) = kg/s$

CFP /REPORT/ BOTH real - *
 Pressure conversion factor: $in(H_2O) * CFP(2) = N/m^2$ (= Pa)

CFQ /REPORT/ BOTH real - *
 Power conversion factor: $Btu/hr * CFQ(2) = W$

CFS	/REPORT/	BOTH	real	-	*
Speed conversion factor: $\text{ft/min} * \text{CFS}(2) = \text{m/s}$					
CFT	/REPORT/	BOTH	real	-	*
Temperature conversion factor: $R * \text{CFT}(2) = K$					
CFU	/REPORT/	BOTH	real	-	*
U-value conversion factor: $\text{Btu/hrft}^2\text{F} * \text{CFU}(2) = \text{W/m}^2\text{K}$					
CFV	/REPORT/	BOTH	real	-	*
Volume conversion factor: $\text{ft}^3 * \text{CFV}(2) = \text{m}^3$					
CFVF	/REPORT/	BOTH	real	-	*
Volumetric flow conversion factor: $\text{ft}^3/\text{min} * \text{CFVF}(2) = \text{m}^3/\text{s}$					
CGSDX	/CGSIL/	BOTH	integer	(MAXCGS)	-
Pointer to week-schedule (or control week-schedule)					
CGSHX	/CGSIL/	BOTH	integer	(MAXCGS)	-
Pointer to day-schedule (or control day-schedule)					
CGSNAM	/CGSNAM/	LC	chr*WRD	(MAXCGS)	-
Name of zone to which the scheduled load applies. This identifies the adjacent zone for which MIX and FAN operations apply.					
CGSOFF	/CGSIL/	BOTH	integer	(MAXCGS)	-
Date (cyclic date form - eq B.1.4) week-schedule ends.					
CGSON	/CGSIL/	BOTH	integer	(MAXCGS)	-
Date (cyclic date form - eq B.1.4) week-schedule begins.					
CGSTYP	/CGSIL/	BOTH	integer	(MAXCGS)	-
Type of action:					
1 = people					
2 = lights					
3 = electric equipment					
4 = gas equipment					
5 = steam equipment					
6 = hot water equipment					
7 = other equipment					
8 = infiltration					
9 = ventilation					
10 = controls					
11 = daylighting					
12 = steam baseboard heat					
13 = hot water baseboard heat					
CGSZON	/CGSIL/	BOTH	integer	(MAXCGS)	-
Number of the zone for which the action applies.					

CL	/RF4/	IP	real	-	-
Lower left element of the layer matrix.					
CLKTIM	/SIMCTL/	LC	integer	-	hr
"Clock time" ($=t_d$ in B.1.1) for selecting scheduled activities.					
CNAME	/ZNAME/	IP	char*WRD	-	-
Construct name (4.13.1).					
CND	/RF/	IP	real	-	$W/m^2 K$
Conductivity of the construct.					
CNTCAP	/CNTPFL/	BOTH	real	(MAXPNT,MAXPFL)	W
Heating/cooling capacity at the control point.					
CNTTMP	/CNTPFL/	BOTH	real	(MAXPNT,MAXPFL)	C
Effective zone temperature of the control point.					
CNVMRT	/ZONL/	LC	real	(MAXZON)	-
Parameter user to predict the mean radiant temperature (TR) and speed zone heat balance convergence.					
COND	/MATDAT/	IP	real	(MAXNL)	W/mK
Conductivity of each layer of construct (from outside).					
CONNAM	/LIBNMS/	LC	char*WRD	(MAXCON)	-
Construct names (2.5.1).					
CONSO	/LIBCTL/	IP	integer	-	-
Pointer to constructs in LNAMEs (location 0).					
CONTEM	/TCDESC/	LC	real	(MAXTMP,MAXZON)	C
Control point temperatures.					
COSBR	/RUNCTL/	IP	real	-	-
Cosine of the building rotation angle.					
COSD	/SLPSSH/	BOTH	real	-	-
Cosine of the solar declination angle.					
COSINC	/GLAS1/	IP	real	-	-
Cosine of the angle of incidence.					
COSL	/EFLHDR/	BOTH	real	-	-
Cosine of the latitude angle.					
COSZR	/BASES/	IP	real	-	-
Cosine of the zone rotation angle.					
CP	/TCDESC/	LC	integer	(MAXZON)	-
Pointer to control profile.					

CPAIR	/AIR/	LC	real	-	Ws/kgK
Specific heat of air.					
CPFLO	/LIBCTL/	IP	integer	-	-
Pointer to control profile in LNames (location 0).					
CPOLD	/ZONL/	LC	integer	(MAZON)	-
Prior hour's pointer to control profile.					
If CP = CPOLD, it is not necessary to recompute the control profile.					
CR	/TCDESC/	LC	real	(MAXZON)	-
Zone temperature control radiant fraction (b in eq K.1.3).					
CS	/RF4/	IP	real	-	-
Lower left element of the total construct matrix.					
CSDECL	/ENVDAT/	BOTH	real	-	-
Cosine of the solar declination angle.					
CT	/SRFIS/	BOTH	real	(MAXSRF)	-
Cosine of surface tile angle (3.2.2 and 4.13.4).					
CT	/RF4/	IP	real	-	-
Lower left element of the total derivative matrix.					
CTF	/BLDCTF/	LC	real	(MAXCTF)	-
Array of conduction transfer functions for all constructs.					
CTFX0	/CONDAT/	BOTH	real	(MAXCON)	W/m ² K
X conduction transfer function for each construct for time = 0.					
CTFY0	/CONDAT/	BOTH	real	(MAXCON)	W/m ² K
Y conduction transfer function for each construct for time = 0.					
CTFZ0	/CONDAT/	BOTH	real	(MAXCON)	W/m ² K
Z conduction transfer function for each construct for time = 0.					
CTHETA	/SRFIS/	BOTH	real	(MAXSRF)	-
Cosine of the angle of incidence of the sun's rays on the surface.					
CTILT	/HTSISL/	BOTH	real	(MAXHTS)	-
Cosine of the heat transfer surface tilt angle.					
CTQ	/RF1/	IP	real	(5)	-
Flux conduction transfer functions (orders 0 through 5).					
CTX	/RF1/	IP	real	(0:5,0:MAXNRF)	W/m ² K
X (external) conduction transfer functions (orders 0 through 5).					
CTY	/RF1/	IP	real	(0:5,0:MAXNRF)	W/m ² K
Y (cross) conduction transfer functions (orders 0 through 5).					

CTZ	/RF1/	IP	real	(0:5,0:MAXNRF)	W/m ² K
Z (internal) conduction transfer functions (orders 0 through 5).					
CWSH	/CNTPTR/	LC	integer	(12,MAXCWS)	-
Control week schedules (2.8): pointers to control day schedules.					
CWSNAM	/LIBNMS/	LC	char*WRD	(MAXCWS)	-
Names of control week schedules (2.8.1).					
CWSO	/LIBCTL/	IP	integer	-	-
Pointer to control week-schedules in L NAMES (location 0).					
D	/RF1/	IP	real	(5)	-
1.0 - RATIO					
DAYOFM	/ENV DAT/	BOTH	integer	-	-
Day of the month number (DM in B.1.2)					
DAYOFS	/SIMCTL/	LC	integer	-	-
Number of days simulated.					
DAYOFW	/ENV DAT/	BOTH	integer	-	-
Day of the week number (DW in B.1.2).					
DAYOFY	/ENV DAT/	BOTH	integer	-	-
Day of the year number (DY in B.1.2).					
DAYTYP	/SIMCTL/	LC	integer	-	-
Day type number (used to select schedules).					
DB	/SOLFAC/	LC	real	(MAXZON)	-
Beam radiation factor for zone (beam converted to diffuse by shade).					
DD	/RF4/	IP	real	-	-
Lower right element of the layer derivative matrix.					
DDBP	/DDENVT/	IP	real	-	Pa
Design day barometric pressure (1.6.6).					
DDCLR	/DDENVT/	IP	real	-	-
Design day clearness number (1.6.9).					
DDDOFM	/DDENVT/	IP	integer	-	-
Design day day-of-month number (1.6.5).					
DDDTYP	/DDENVT/	IP	integer	-	-
Design day type number (1.6.12).					
DDMDBT	/DDENVT/	IP	real	-	C
Design day maximum dry bulb temperature (1.6.2).					

DDMON	/DDENVVT/	IP	integer	-	-
Design day month number (1.6.5).					
DDRN	/DDENVVT/	IP	integer	-	-
Design day rain indicator (1=rain) (1.6.10).					
DDSNW	/DDENVVT/	IP	integer	-	-
Design day snow indicator (1=snow) (1.6.11).					
DDTRNG	/DDENVVT/	IP	real	-	C
Design day temperature range (from 1.6.2 and 1.6.3).					
DDWBT	/DDENVVT/	IP	real	-	C
Design day wet bulb temperature (1.6.4).					
DDWDIR	/DDENVVT/	IP	real	-	degrees
Design day wind direction (1.6.8).					
DDWSPD	/DDENVVT/	IP	real	-	m/s
Design day wind speed (1.6.7).					
DELT	/REPORT/	BOTH	real	-	*
Temperature conversion factor: $(F+DELT(2)) * CFT(2) = C$					
DEM	/RUNCTL/	IP	logical	-	-
Detailed error messages (1.1.3).					
DENS	/MATDAT/	IP	real	(MAXNL)	kg/m ³
Material density (2.4.5).					
DG	/SOLFAC/	LC	real	(MAXZON)	-
Ground reflected diffuse radiation factor for the zone.					
DIR	/ENVDAT/	BOTH	real	(24)	degrees
Wind direction (G.1.3).					
DL	/RF4/	IP	real	-	-
Lower right element of the layer matrix.					
DS	/RF4/	IP	real	-	-
Lower right element of the total construct matrix.					
DS	/SOLFAC/	LC	real	(MAXZON)	-
Diffuse sky radiationn factor for the zone.					
DSH	/SCHDLS/	LC	real	(24,MAXDSH)	-
Day schedules (2.2).					
DSHNAM	/LIBNMS/	LC	char*WRD	(MAXDSH)	-
Day schedule names (2.2.1).					

DSTIND	/ENV DAT/	BOTH	integer	-	-
Daylight savings time indicator.					
DSO	/LIBCTL/	IP	integer	-	-
Pointer to day schedules in L NAMES (location 0).					
DT	/RF4/	IP	real	-	-
Lower right element of total derivative matrix.					
DTR	/REPORT/	BOTH	real	-	*
Conversion factor: degrees * DTR = radians.					
DYS	/CALNDR/	BOTH	char*3	(12)	-
Names of day types (2.3.3).					
EELOAD	/ZONL/	LC	real	(MAXZON)	Wh
Zone electric load (lights plus electric equipment).					
EFILL	/ENV DAT/	BOTH	integer	(3)	-
Array filler.					
EFSTR	/TCDESC/	LC	integer	(MAXZON)	-
Pointer to temperature control range (p in K.1.1).					
EMIT	/MATDAT/	IP	real	(MAXNL)	-
Emittance o material for thermal wavelength radiation (2.4.8).					
EMUI	/RUNCTL/	IP	integer	-	-
Input in English (2) or metric (1) units (1.1.7).					
EMUO	/REPORT/	BOTH	integer	-	-
Output in English (2) or metric (1) units (1.1.7).					
ENDATE	/SIMCTL/	LC	integer	-	-
Cyclic date on which current shadowing data ends.					
ENV DAT	/ENV DAT/	BOTH	integer	(256)	-
Environment data - all equivalenced to this array.					
ENVREC	/SIMCTL/	LC	integer	-	-
Environment record number (index to ENV TFL direct access file).					
ENV TNR	/SIMCTL/	LC	integer	-	-
Environment number.					
EQTIME	/ENV DAT/	BOTH	real	-	hr
Equation of time.					
EQTM	/SLPSSH/	BOTH	real	-	hr
Equation of time.					

ETITLE /TITLES/ BOTH char*DESC (13) -
 Environment titles (1.5.1 and 1.6.1).

EVDAT /ENVDAT/ BOTH integer -
 Julian date (JD in B.1.2).

EXTC /GLAS9/ IP real (4) -
 Product of pane extinction coefficient times thickness.

EXTCW /GLAS10/ IP real (4,MAXNWL) -
 Product of pane extinction coefficient times thickness for each
 wavelength.

EVTR. /TCDESC/ LC integer (MAXZON) -
 Pointer to ventilation control temperature range.

FACTOR /ZONL/ LC real (MAXZON) C
 Intermediate result for computing mean radiant temperature
 (TRL_n if H.2.4c).

FAFS /ZONISL/ BOTH integer (MAXZON) -
 Number of the first air flow opening in the zone description.

FAHS /ZONL/ LC real (MAXZON) m^3/s
 Net air flow from the air handling system into the zone (set to 0).

FAREA /AFSIL/ BOTH real (MAXAFS) m^2
 Air flow opening area (4.14.1).

FBKSHC /SHDCTL/ LC integer - -
 Pointer to HC location for inside (back) surface calculations.

FCOS1 /AFSIL/ BOTH real (MAXAFS) -
 Direction cosine of opening for computing relative wind direction.

FCOS2 /AFSIL/ BOTH real (MAXAFS) -
 Direction cosinf of opening for computing relative wind direction.

FCOUNT /SIMCTL/ LC integer - -
 Number of air flow iterations from start of simulation.

FEXP /AFSIL/ BOTH real (MAXAFS) -
 Air flow opening exponent (4.14.2).

FD /GLAS9/ IP real (2,4) -
 Thickness of reflective films (D in D.4.4a).
 (side, pane number)

FGSSHC /SHDCTL/ LC integer - -
 Pointer to HC location for general shadowing surface calculations.

FHTS /ZONISL/ BOTH integer (MAXZON) -
 Number of the first heat transfer surface in the zone description.

FINSHC /SHDCTL/ LC integer - -
 Pointer to HC location for inside solar distribution calculation.

FK /GLAS9/ IP real (2,4) -
 Reflective film extinction coefficient (k_2 in D.4.1).
 (side, pane number)

FKW /GLAS10/ IP real (4,MAXNWL) -
 Reflective film extinction coefficient (k_2 in D.4.1).
 (pane number, wavelength)

FLRTFP /CONDAT/ BOTH integer (MAXCON) -
 Pointers to flux components of conduction transfer functions.

FLXHPE /HTSIL/ BOTH integer (MAXHTS) -
 Pointers to external flux histories.

FLXHPI /HTSIL/ BOTH integer (MAXHTS) -
 Pointers to internal flux histories.

FN /GLAS9/ IP real (2,4) -
 Reflective film index of refraction (n_2 in D.4.1).
 (side, pane number)

FNW /GLAS10/ IP real (4,MAXNWL) -
 Reflective film index of refraction (n_2 in D.4.1).
 (pane number, wavelength)

FP /ZONL/ LC integer (MAXZON) -
 Pointer to scheduled fan action (RCGS).

FRVLHC /SHDCTL/ LC integer - -
 Pointer to HC location for setback (reveal) calculations.

FSBSHC /SHDCTL/ LC integer - -
 Pointer to HC location for subsurface calculations.

FSG /HTSISL/ BOTH real (MAXHTS) -
 Angle factor between the surface and the ground (4.13.8 and E.5.1 and
 I.2.6c).

FSRF /ZONISL/ BOTH integer (MAXZON) -
 Number of first surface in zone description.

FSS /HTSISL/ BOTH real (MAXHTS) -
 Angle factor between the surface and the sky (4.13.7 and E.5.1 and
 I.2.6a,b).

FTRANS	/MATDAT/	IP	real	(MAXNL)	-
Transmittance of pane of glass with reflective film (2.4.11).					
G	/HTSL/	LC	real	(MAXHTS)	W/m ² K
Constant part of HR (H.2.4a).					
GELOAD	/ZONL/	LC	real	(MAXZON)	Wh
Gas equipment load.					
GN	/GLAS9/	IP	real	(4)	-
Index of refraction of pane.					
GNW	/GLAS10/	IP	real	(4,MAXNWL)	-
Wavelength dependent indices of refraction.					
GRSNR	/SHDCTL/	LC	integer	-	-
Surface number of the general (base) shadow receiving surface.					
GSSNR	/SHDCTL/	LC	integer	-	-
Surface number of the general shadowing surface.					
GTND	/SIMCTL/	LC	logical	-	-
"Go to next day." (False during temperature history initialization.)					
HC	/HTSL/	LC	real	(MAXHTS)	W/m ² K
Inside convection coefficient.					
HCA	/HCFS/	LC	integer	(MAXHCV,MAXHCS)	-
'A' homogeneous coordinates of side of figure.					
HCAREA	/HCFS/	LC	real	(MAXHCS)	m ²
Area of homogeneous coordiante figure.					
HCB	/HCFS/	LC	integer	(MAXHCV,MAXHCS)	-
'B' homogeneous coordinates of sides of figure.					
HCC	/HCFS/	LC	integer	(MAXHCV,MAXHCS)	-
'C' homogeneous coordinates of sides of figure.					
HCMULT	/SHDCTL/	LC	real	-	-
Homogeneous coordinate multiplier: convert dimensions in meters to integer values in millimeters.					
HCNS	/HCFS/	LC	integer	(MAXHCS)	-
Surface numbers of back surface homogeneous coordinate figures.					
HCNV	/HCFS/	LC	integer	(MAXHCS)	-
Number of vertices of homogeneous coordinate figures.					
HCOUNT	/SIMCTL/	LC	integer	-	-
Number of heat balance iterations in current hour.					

HCT	/HCFS/	LC	real	(MAXHCS)	-
Transmittances of homogeneous coordinate figures.					
HCX	/HCFS/	LC	integer	(MAXHCV,MAXHCS)	-
'X' homogeneous coordinates of vertices of figure.					
HCY	/HCFS/	LC	integer	(MAXHCV,MAXHCS)	-
'Y' homogeneous coordinates of vertices of figure.					
HOC	/HTSIL/	BOTH	real	(MAXHTS)	-
Constant part of detailed outside convection coefficient.					
HOLIND	/ENVDAT/	BOTH	integer	-	-
Holiday indicator (1 = holiday; 0 = not holiday; 2 = special 1; 3 = special 2, ...)					
HR	/HTSL/	LC	real	(MAXHTS)	W/m ² K
Surface radiative conductance (H.2.3 and H.2.4d).					
HRS	/CALNDR/	BOTH	char*2	(24)	-
Hours (for reports).					
HTBAL	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Heat balance method (3.1.5).					
HTS	/SHDCTL/	LC	integer	-	-
Heat transfer surface number.					
HTSS	/SHDCTL/	LC	integer	-	-
Heat transfer subsurface number.					
HWLOAD	/ZONL/	LC	real	(MAXZON)	Wh
Hot water load.					
ICOUNT	/SIMCTL/	LC	integer	-	-
Number of non-convergent heat balance iterations.					
IHALG	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Inside convection algorithm (3.1.7).					
INF	/ZONL/	LC	real	(MAXZON)	W/C
Simple infiltration capacity rate.					
INTSHD	/GLAS1/	IP	integer	-	-
0 = no interior shade; 1 = interior shade present.					
IP	/ZONL/	LC	integer	(MAXZON)	-
Pointer to scheduled infiltration (RCGS).					

ISABS	/CONDAT/	BOTH	real	(MAXCON)	-	
Inside surface short wavelength absorptance (2.4.7 and 2.5.7).						
ISABSF	/HTSIS/	BOTH	real	(MAXHTS)	-	
Fraction of beam solar gain absorbed directly by surface. The remainder becomes a diffuse gain to the zone.						
ISENV	/HTSISL/	BOTH	integer	(MAXHTS)	-	
Surface inside environment number (= zone number).						
ISHC	/GLAS11/	IP	integer	-	-	
1 indicates properties of interior shade are independent of theta. 0 not yet used.						
ISSC	/SSCISL/	BOTH	integer	(9,MAXSSC)	-	
Equivalenced to RSSC.						
ITABS	/CONDAT/	BOTH	real	(MAXCON)	-	
Inside surface thermal absorptance/emittance (2.4.8 and 2.5.8).						
IVABSF	/CONDAT/	BOTH	real	(MAXCON)	-	
Fraction of visible diffuse light absorbed by each surface.						
IZPHTS	/HTSISL/	BOTH	integer	(MAXHTS)	-	
Heat transfer surface number of opposite side of interzone surface. Equivalenced to FSS to save storage space.						
JDATE	/SHDCTL/	LC	integer	-	-	
Julian date.						
JDATE0	/SHDCTL/	LC	integer	-	-	
Julian date at start of shadow group-of-days.						
JJ	/GLAS4/	IP	integer	-	-	
Inner or outer surface indicator.						
KELVIN	/REPORT/	BOTH	real	-	-	C
Conversion factor: $C + \text{KELVIN} = K$						
KEY1	/ALIST/	IP	char*WRD	-	-	
Name of current input section.						
KEY2	/ALIST/	IP	char*WRD	-	-	
Name of current input key.						
KK	/RF2/	IP	real	(3,MAXNRT)	-	
Combination of residue elements.						
KIP	/HTSL/	LC	real	(MAXHTS)	-	W/m^2
Constant part of inside conductive flux (C.1.5).						

KOP	/HTSL/	LC	real	(MAXHTS)	W/m ²
Constant part of outside conductive flux (C.1.7).					
KPTR	/HTSISL/	BOTH	integer	(MAXHTS)	-
Pointer to construct data.					
LAFS	/ZONISL/	BOTH	integer	-	-
Number of the last air flow opening in the zone description.					
LALOAD	/ZONL/	LC	real	(MAXZON)	Wh
Latent heat gain.					
LAMBDA	/GLAS1/	IP	real	-	nm
Wave length of light for optical calculations.					
LATD	/EFLHDR/	BOTH	real	-	degrees
Location latitude (1.3.2).					
LCNVG1	/RUNCTL/	IP	real	-	-
	/SIMCTL/	LC			
Loads convergence.					
LCNVG2	/RUNCTL/	IP	real	-	W
	/SIMCTL/	LC			
Minimum load.					
LDESC	/LIBNMS/	IP	char*DESC	-	-
Location description (1.3.1).					
LENGTH	/MATDAT/	IP	real	(MAXNL)	m
Thickness of layer (2.5.3).					
LFLAGS	/LIBCTL/	LIBCTL	logical	(7)	-
Library report flags (2.1.3).					
LFLAGS	/SIMCTL/	LC	logical	(4)	-
Temporary report flags corresponding to RFLAGS 21-24.					
LHTS	/ZONISL/	BOTH	integer	(MAXZON)	-
Number of the last heat transfer surface of the zone.					
LIBNAM	/LIBNMS/	IP	char*WRD	-	-
Library name (2.1.1).					
LNames	/LIBNMS/	IP	char*WRD	(256)	-
Names of library entries - used as index to library data.					
LOCHCA	/SHDCTL/	LC	integer	-	-
Current location in the homogeneous coordinate arrays.					

LOCSCM	/SHDCTL/	LC	integer	-	-
Current location in the shadowing combinations (SHDCMB) array.					
LONG	/EFLHDR/	BOTH	real	-	degrees
Location longitude (1.3.3).					
LR	/RF2/	IP	real	(MAXNL)	m ² K/W
Thermal resistance of layer.					
LRAIN	/SIMCTL/	LC	logical	-	-
Rain indicator for the hour.					
LSRF	/ZONISL/	BOTH	integer	(MAXZON)	-
Surface number of the last surface of the zone.					
LTITLE	/TITLES/	BOTH	char*DESC	-	-
Location title (1.3.1).					
LUSED	/LIBCTL/	IP	logical	(MAXLNM)	-
Set to TRUE when a library name is referenced.					
MATLO	/LIBCTL/	IP	integer	-	-
Pointer to materials (location 0).					
MAXIT	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Maximum number of heat balance iteration in an hour (3.1.3).					
MAXPAN	/GLAS9/	IP	integer	-	-
Maximum number of glass pane in a window.					
MCPI	/ZONL/	LC	real	(MAXZON)	W/K
Mass flor rate time specific heat for infiltration.					
MCPM	/MIXING/	LC	real	(MAXZON)	W/K
Mass flow rate times specific heat for mixing.					
MCPTM	/MIXING/	LC	real	(MAXZON)	W
MCPM times air temperature for mixing.					
MCPV	/ZONL/	LC	real	(MAXZON)	W/K
Mass flor rate times specific heat for ventilation.					
MDHMNT	/BLDRPT/	LC	integer	-	-
Month/day/hour at which minimum temperture (BMNT) occurs.					
MDHMXC	/BLDRPT/	LC	integer	-	-
Month/day/hour at which maximum cooling load (BMXC) occurs.					
MDHMXH	/BLDRPT/	LC	integer	-	-
Month/day/hour at which maximum heating load (BMXC) occurs.					

MDHMXT	/BLDRPT/	LC	integer	-	-
Month/day/hour at which maximum temperture (BMXT) occurs.					
MERID	/EFLHDR/	LC	real	-	degrees
Degrees east of time zone central meridian.					
MIRRX	/BASES/	IP	logical	-	-
Mirror X coordinates (4.1.5).					
MIRRY	/BASES/	IP	logical	-	-
Mirror Y coordinates (4.1.6).					
MISS	/SHDCTL/	LC	integer	-	-
Results of polygon overlap calculation:					
1 = no overlap					
2 = NS1 completely within NS2					
3 = NS2 completely within NS1					
4 = partial overlap					
MNAMES	/MATNMS/	IP	char*WRD	(MAXNL)	-
Names of materials (2.4.1).					
MNS	/CALNDR/	BOTH	char*3	(12)	-
Month names.					
MONTH	/ENVDAT/	BOTH	integer	-	-
Month number.					
MP	/ZONL/	LC	integer	(MAXZON)	-
Pointer to scheduled mixing (RCGS).					
MTYPE	/MATDAT/	IP	integer	(MAXNL)	-
Material type (2.4.15, 2.4.16, 2.4.17):					
0 = opaque, 1 = glass, 2 = shade, 3 = air.					
MXCDS	/LIBCTL/	IP	integer	-	-
Maximum number of control day=schedules (2.1.3).					
MXCONS	/LIBCTL/	IP	integer	-	-
Maximum number of constructs (2.1.3).					
MXCPFL	/LIBCTL/	IP	integer	-	-
Maximum number of control profiles (2.1.3).					
MXCWS	/LIBCTL/	IP	integer	-	-
Maximum number of control week=schedules (2.1.3).					
MXDS	/LIBCTL/	IP	integer	-	-
Maximum number of day=schedules (2.1.3).					

MXMATL	/LIBCTL/	IP	integer	-	-
Maximum number of materials (2.1.3).					
MXWS	/LIBCTL/	IP	integer	-	-
Maximum number of week-schedules (2.1.3).					
NAFS	/SIMCTL/	LC	integer	-	-
Total number of air flow opening descriptions.					
NBKS	/SHDCTL/	LC	integer	-	-
Number of back surfaces.					
NBKSHC	/SHDCTL/	LC	integer	-	-
Number of back figures in HC arrays.					
NC	/IZPDAT/	IP	integer	-	-
Number of temperature CTF to determine interzone surface match.					
NCDS	/LIBCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Number of control day-schedules.					
NCGS	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Number of zone control and general schedules (RCGS).					
NCMB	/SHDCMB/	LC	integer	-	-
Number of shadowing combinations.					
NCL	/RF/	IP	integer	-	-
Number of conductive layers in construct.					
NCON	/SIMCTL/	LC	integer	-	-
Number of constructs.					
NCONS	/LIBCTL/	IP	integer	-	-
Number of constructs.					
NCPFL	/LIBCTL/	IP	integer	-	-
Number of control profiles.					
NCTF	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Number of conduction transfer functions coefficients.					
NCWS	/LIBCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Number of control week-schedules.					
NDS	/LIBCTL/	IP	integer	-	-
Number of day-schedules.					

NDSH	/SIMCTL/	LC	integer	-	-
Number of day-schedules.					
NEVTRC	/EFLHDR/	BOTH	integer	-	-
Number of ventilation temperature ranges.					
NFRTEC	/CONDAT/	BOTH	integer	(MAXCON)	-
Number of flux referring CTF coefficients.					
NGSS	/SHDCTL/	LC	integer	-	-
Number of general shadowing surfaces.					
NGSSHCH	/SHDCTL/	LC	integer	-	-
Number of general shadowing figures in homogeneous coordinate arrays.					
NGTP	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Number of constructs with optical coefficients.					
NHCS	/SHDCTL/	LC	integer	-	-
Maximum number of homogeneous coordinate figures used.					
NHTS	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Number of heat transfer surfaces.					
NINSHCH	/SHDCTL/	LC	integer	-	-
Number of inside surfaces (shadow overlaps on back surfaces) in HC arrays.					
NIN1	/SHDCTL/	LC	integer	-	-
Number of vertices of HC figure NS1 within HC figure NS2.					
NIN2	/SHDCTL/	LC	integer	-	-
Number of vertices of HC figure NS2 within HC figure NS1.					
NIZP	/IZPDAT/	IP	integer	-	-
Number of unmatched interzone surfaces.					
NL	/RF/	IP	integer	-	-
Number of layers in construct.					
NMATL	/LIBCTL/	IP	integer	-	-
Number of materials in library.					
NOFOCC	/ZONL/	LC	integer	(MAXZON)	-
Number of occupants (4.2.2).					
NOIMI	/HTSISL/	BOTH	integer	(MAXHTS)	-
True if there is never inside movable insulation (4.18) on the surface.					
Equivalenced to FSG to save space.					

NOSC	/SIMCTL/	LC	integer	-	-
Number of "other side coefficient" (4.16) descriptions.					
NPANES	/GLAS1/	IP	integer	-	-
Number of glass panes in window construct.					
NPFL	/SIMCTL/	LC	integer	-	-
Number of control profiles.					
NQ	/IZPDAT/	IP	integer	-	-
Number of flux CTF coefficients for matching interzone surfaces.					
NRATIO	/RF2/	IP	integer	-	-
Number of RATIO.					
NRCTR	/TCDESC/	LC	(MAXZON)	-	-
Number of control temperature ranges in control profile.					
NRDAYS	/EFLHDR/	BOTH	integer	(13)	-
Number of days in the simulation environment.					
NRENVS	/EFLHDR/	BOTH	integer	-	-
Number of environments on the environemnt file.					
NRF	/RF/	IP	integer	-	-
Number of temperature CTF calculated.					
NRSTAT	/CNTPFL/	BOTH	integer	(MAXPFL)	-
Number of control points in control profile.					
NRT	/RF/	IP	integer	-	-
Number of roots computed.					
NRVLHC	/SHDCTL/	LC	integer	-	-
Number of reveal figures in HC arrays.					
NRVTR	/TCDESC/	LC	integer	(MAXZON)	-
Number of ventilation temperature ranges.					
NSBS	/SHDCTL/	LC	integer	-	-
Number of door/window subsurfaces.					
NSBSHC	/SHDCTL/	LC	integer	-	-
Number of subsurface figures in the homogeneous coordinate arrays.					
NSRF	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Number of surfaces (all except internal mass).					
NSSC	/RUNCTL/	IP	integer	-	-
Number of special surface coefficients (RSSC).					
	/SIMCTL/	LC			

NSURFS	/GLASI/	IP	integer	-	-
Number of optical surfaces in window construct (glass + shade).					
NS1	/SHDCTL/	LC	integer	-	-
Number of the HC figure being overlapped.					
NS2	/SHDCTL/	LC	integer	-	-
Number of the HC figure doing the overlapping.					
NS3	/SHDCTL/	LC	integer	-	-
HC location to place results of overlap.					
NTFH	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Number of temperature/flux history terms (with space for time shift).					
NTIMES	/PSYCOM/	IP	integer	-	-
Number of times specific psychrometric errors have occurred.					
NTRTFC	/CONDAT/	BOTH	integer	(MAXCON)	-
Number of temperature CTF coefficients.					
NUAFS	/AFSDAT/	IP	integer	-	-
Number of unmatched interzone air flow openings.					
NV	/SRFIS/	BOTH	integer	(MAXSRF)	-
Number of vertices of surface.					
NVERTS	/VERTS/	IP	integer	-	-
Number of vertices of surface.					
NVS	/SHDVRT/	LC	integer	-	-
Number of vertices of the shadow.					
NVT	/SHDVRT/	LC	integer	-	-
Number of vertices of the transformed/clipped surface.					
NV1	/SHDCTL/	LC	integer	-	-
Number of vertices of figure NS1.					
NV2	/SHDCTL/	LC	integer	-	-
Number of vertices of figure NS2.					
NV3	/SHDCTL/	LC	integer	-	-
Number of vertices of figure NS3.					
NWL	/GLAS10/	IP	integer	-	-
Number of wavelengths used to evaluate optical properties.					
NWS	/LIBCTL/	IP	integer	-	-
Number of week-schedules.					

NWSH	/SIMCTL/	LC	integer	-	-
Number of week-schedules.					
NXMI	/SIMCTL/	LC	integer	-	-
Number of exterior movable insulation (4.17) descriptions.					
NZON	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Number of zones.					
OAMFL	/ZONL/	LC	real	(MAXZON)	kg/s
Infiltration mass flow rate.					
OBP	/ENVDAT/	BOTH	real	(24)	Pa
Barometric pressure (absolute).					
ODB	/ENVDAT/	BOTH	real	(24)	C
Ambient dry bulb temperature.					
OFFDAT	/SRFIS/	BOTH	integer	(MAXSRF)	-
Stop date (cyclic) for shadowing surfaces.					
OHALG	/RUNCTL/	IP	integer	-	-
	/SIMCTL/	LC			
Outside surface coefficient algorithm (3.1.6).					
OHR	/ENVDAT/	BOTH	real	(24)	-
Humidity ratio of ambient air.					
OLDW	/RUNCTL/	IP	logical	-	-
Use old WTHRFL (1.1.6).					
ONDAT	/SRFIS/	BOTH	integer	(MAXSRF)	-
Start date (cyclic) for shadowing surfaces.					
ORDER	/RF/	IP	integer	-	-
Order (number of flux coefficients) of conduction transfer functions.					
OROUGH	/CONDAT/	BOTH	integer	(MAXCON)	-
Surface outside roughness number (2.4.14 and 2.5.6).					
OSABS	/CONDAT/	BOTH	real	(MAXCON)	-
Surface outside solar absorptance (2.4.7 and 2.5.4).					
OSENV	/HTSISL/	BOTH	integer	(MAXHTS)	-
Surface outside environment number:					
>0 = adjacent zone number					
-1 = internal mass					
-2 = partition					
-3 = envelope surface					
-4 = surface with OSC (4.16)					

OTABS	/CONDAT/	BOTH	real	(MAXCON)	-
Surface outside thermal absorptance/emittance (2.4.8 and 2.5.8).					
OTLOAD	/ZONL/	LC	real	(MAXZON)	Wh
Load from "other" sources (4.4.7).					
OWB	/ENVDAT/	BOTH	/real	(24)	C
Ambient wet bulb temperature.					
PFC	/RF2/	IP	real	(MAXNRT)	-
Components of pulse functions.					
PFLNAM	/LIBNMS/	LC	char*WRD	(MAXPFL)	-
Names of control profiles.					
PI	/REPORT/	BOTH	real	-	-
$\pi = 3.14159\dots$					
PP	/ZONL/	LC	integer	(MAXZON)	-
Pointer to people gains (in RCGS).					
PRAIR	/AIR/	LC	real	-	-
Prandtl number of air.					
PS	/AFSIL/	BOTH	real	(MAXAFS)	Pa
Stack pressure (G.2.3).					
PTITLE	/TITLES/	BOTH	char*DESC	-	-
Project title (1.1.1).					
PW	/AFSIL/	BOTH	real	(MAXAFS)	Pa
Wind pressure (G.1.3).					
PZ	/ZONL/	LC	real	(MAXZON)	Pa
Zone pressure (G.1.3).					
Q	/GLAS12/	IP	real	(16)	-
Dependent variable in optical properties curve fits.					
QBV	/ZONL/	LC	real	(MAXZON)	W
Total beam sunlight entering zone (for daylight calculations).					
QC	/ZONL/	LC	real	(MAXZON)	W
Solar gain convected from shading devices.					
QD	/ZONL/	LC	real	(MAXZON)	W
Total diffuse solar gain in zone (includes beam radiation diffused after first surface absorption in zone).					
QDV	/ZONL/	LC	real	(MAXZON)	W
Total diffuse sunlight entering zone (for daylight calculations).					

QFSTDC	/TCDESC/	LC	real	(MAXRNG,MAXZON)	W/K
LT in (K.1.2a).					
QFSTIF	/TCDESC/	LC	real	(MAXRNG,MAXZON)	W
LC in (K.1.2a).					
QFVTDC	/TCDESC/	LC	real	(4,MAXZON)	W/K
Ventilation coefficient (similar to QFSTDC).					
QFVTIF	/TCDESC/	LC	real	(4,MAXZON)	W
Ventilation coefficient (similar to QFSTIF).					
QL	/ZONL/	LC	real	(MAXZON)	W
Total long wave radiant gains in zone (QLn in H.2.5).					
QOCCON	/ZONL/	LC	real	(MAXZON)	W
Convective gains from occupants.					
QOCLAT	/ZONL/	LC	real	(MAXZON)	W
Latent gains from occupants.					
QOCRAD	/ZONL/	LC	real	(MAXZON)	W
Radiant gains from occupants.					
QS	/ZONL/	LC	real	(MAXZON)	W
Total diffuse, short wavelength gains in zone.					
QSA	/ZONL/	LC	real	(MAXZON)	W
Solar radiation available for daylighting.					
QSI	/HTSL/	LC	real	(MAXHTS)	W/m ²
Short wave radiant flux absorbed by inside surfaces.					
QSM	/HTSL/	LC	real	(MAXHTS)	W/m ²
Short wave radiant flux absorbed by movable insulation.					
QSO	/HTSL/	LC	real	(MAXHTS)	W/m ²
Short wave radiant flux absorbed by outside surface.					
R	/GLAS2/	IP	real	(2,4,2)	-
Reflectances of single pane of glass (polarization, pane number, side of incidence).					
RAIN	/ENVDAT/	BOTH	integer	-	-
Rain indicator (24 hours, compressed).					
RALOAD	/ZONL/	LC	real	(MAXZON)	Wh
Return air load (part of sensible gain from lights 4.3.3).					
RATIO	/RF/	IP	real	(MAXNRT)	-
Ratios defining higher order conduction transfer functions.					

RCGS /CGSIL/ BOTH real (5,MAXCGS) -
 Data for scheduled loads; varies according to CGSTYP.
 Type = 1 (people - 4.2)
 1 = number of occupants
 2 = activity level W
 3 = fraction radiant
 Type = 2 (lights - 4.3)
 1 = design lighting load W
 2 = fraction of load to return air
 3 = fraction radiant (long wavelengths)
 4 = fraction visible (short wavelengths)
 5 = fraction of load replaceable by daylight
 Types = 3, 4, 5, 6, and 7 (equipment - 4.4)
 1 = design load W
 2 = fraction latent
 3 = fraction radiant
 4 = fraction lost
 5 = fraction convected
 Type = 8 (infiltration - 4.5)
 1 = design volumetric flow m^3/s
 2 = constant part of Achenbach-Coblentz equation
 3 = temperature part
 4 = velocity part s/m
 5 = velocity squared part s^2/m^2
 Type = 9 (ventilation - 4.6)
 1 = design volumetric flow m^3/s
 2 = minimum temperature C
 3 = maximum temperature C
 4 = temperature difference C
 Type = 10 (two-zone mixing - 4.7)
 1 = design volumetric flow m^3/s
 4 = temperature difference C
 Type = 11 (whole house fan - 4.8)
 1 = design volumetric flow m^3/s
 4 = desired temperature C
 Type = 12 (controls - 4.9)
 1 = maximum heating capacity W
 2 = maximum cooling capacity W
 3 = fraction of control based on mean radiant temperature
 Type = 13 (daylight - 4.10)
 1 = fraction beam usable
 2 = fraction diffuse usable
 Types = 14 and 15 (baseboard heat - 4.11)
 1 = temperature at lower control point C
 2 = temperature at upper control point C
 3 = capacity at upper control point W
 4 = slope of curve W/C
 5 = fraction radiant

RCOUNT /SIMCTL/ LC integer -
 Number of heat balance iterations.

REFRAC	/MATDAT/	IP	real	(MAXNL)	-
Index of refraction (2.4.10).					
REPEAT	/RF/	IP	logical	-	-
If true, repeat root search with smaller SINC.					
RFLAGS	/REPORT/	BOTH	logical	(RFGLEN)	-
Reports flags:					
1 = dump PROJECT and LIBRARY data					
2 = dump DDY and WTAP data					
3 = dump CTF calculations					
4 = dump glass calculations					
5 = dump DSS data					
6 = dump ZONE data					
7 = dump cross reference values					
8 = dump SIMBLD as read by LC					
9 = report description of zone					
13 = report sunlit areas					
14 = report shadowing combinations					
15 = dump shadow calculation controls					
16 = dump shadow calculations					
20 = dumps 21-24 during warm-up period					
21 = dump primary zone data					
22 = dump constant load components					
23 = dump variables					
24 = dump temperature and flux histories					
25 = dumps 21-24 on WED nearest 21st of month					
RHO	/GLAS4/	IP	real	(2,4)	-
Energy reflectances of the air-glass interfaces (polarization, interface and direction)					
ROOT	/RF2/	IP	real	(MAXNRT)	-
Roots for computing response factors.					
ROUGH	/MATDAT/	IP	integer	(MAXNL)	-
Material roughness number (2.4.14).					
RR	/GLAS3/	IP	real	(2,2)	-
Reflectance of a window system (polarization, side of incidence).					
RR	/RF/	IP	real	-	m ² K/W
Thermal resistance of single layer slab.					
RRB	/GLAS6/	IP	real	(2,16)	-
Reflectance of a window system for beam light (angle number, polarization).					
RRBW	/GLAS8/	IP	real	(16)	-
Outside beam reflectances integrated over wavelength and polarization (angle number).					

RRD /GLAS5/ IP real (2,2) -
 Reflectances of a window system for diffuse light
 (polarization, side of incidence).

RRDW /GLAS7/ IP real - -
 Outside diffuse reflectance integrated over wavelength and
 polarization.

RSD /GLAS11/ IP real (2) -
 Reflectance of shade for diffuse light.

RSSC /SSCISL/ BOTH real (9,MAXSSC) -
 Array of special surface coefficients created by OSC (4.16), EMI (4.17)
 and IMI (4.18). Equivalenced to ISSC for integer values.
 For OSC, RSSC(N,SSC) =
 N=1: 3 (integer)
 N=2: convection coefficient (4.16.1)
 N=3: zone air temperature part (4.16.2)
 N=4: ambient air temperature part (4.16.3)
 N=5: constant temperature (4.16.4)
 N=6: constant temperature part (4.16.5)
 N=7: ground temperature part (4.16.6)
 N=8: wind speed factor (4.16.7)
 N=9: heat transfer surface number of base surface (integer)
 For EMI, RSSC(N,SSC) =
 N=1: 1 (integer)
 N=2: U-value of construct
 N=3: outside solar absorptance
 N=4: outside thermal absorptance
 N=5: surface roughness number (integer)
 N=6: start date (cyclic) (4.17.3) (integer)
 N=7: stop date (cyclic) (4.17.3) (integer)
 N=8: positive value = pointer to day-schedule (4.17.2),
 -1 = sun up control, -2 = sun down control (integer)
 N=9: heat transfer surface number of the base surface (integer)
 For IMI, RSSC(N,SSC) =
 N=1 through N=7 and N=9: same as EMI
 N=8: positive value = pointer to day-schedule (4.18.2),
 -1 = maximum heat gain, -2 = maximum heat loss (integer)

RSO /GLAS11/ IP real - -
 Reflectance of shade at normal incidence (2.4.12).

RTD /REPORT/ BOTH real - *
 Conversion factor: radians * RTD = degrees

RVAL /MATDAT/ IP real (MAXNL) m²K/W
 R-value of material (2.4.6).

S /SHDCTL/ LC real - -
 Y displacement of a shadow in the surface coordinate system (E.2.3b).

SA	/SRFIS/	BOTH	real	(MAXSRF)	-
Sine of surface azimuth angle (4.13.3).					
SABS	/MATDAT/	IP	real	(MAXNL)	-
Solar absorptance of the material (2.4.7).					
SAREA	/HTSIS/	BOTH	real	(MAXHTS)	m ²
Sunlit area of the surface.					
SBSNR	/SHDCTL/	LC	integer	-	-
Subsurface number; pointer to SRFIS arrays.					
SFAZIM	/HTSIL/	BOTH	real	(MAXHTS)	degrees
Surface azimuth angle (3.2.1 and 4.13.3).					
SHAPE	/VERTS/	IP	integer	-	-
Surface shape number: 1=triangle, 2=quadrilateral, 3=rectangle, 4=door/window, 5=overhang, 6=projection, 7=left fin, 8=right fin.					
SHDCF	/MATDAT/	IP	real	(MAXNL)	-
Shading coefficient of material (2.4.13).					
SHDCMB	/SHDCMB/	LC	integer	(MAXCMB)	-
Shadowing combinations array. For each base, envelope surface: surface number, number of shadowing surfaces, number of back surfaces, number of subsurfaces, list of shadowing surfaces, list of back surfaces, list of subsurfaces.					
SHDGRP	/SIMCTL/	LC	integer	-	-
Shadow group (of days) number.					
SHDREC	/SIMCTL/	LC	integer	-	-
Shadow file record number.					
SHDSRF	/SRFIS/	BOTH	integer	(2,MAXSRF)	-
Surface data array (for shadowing).					
SHRSRF(1,NS) =					
+1 to +MAXHTS: Heat transfer surface number (HTS or I) of surface NS.					
0 : Detached shadowing surface.					
-1 : Shadowing subsurface.					
SHRSRF(2,NS) =					
+1 to +MAXHTS: Coordinates are relative to global origin.					
-1 to -MAXHTS: Coordinates are relative to surface -HTS.					
SINBR	/RUNCTL/	IP	real	-	-
Sine of the building rotation angle (3.1.1).					
SINC	/RF/	IP	real	-	-
Root search increment.					

SIND	/SLPSSH/	BOTH	real	-	-
Sine of the solar declination angle.					
SINL	/EFLHDR/	BOTH	real	-	-
Sine of the location latitude (1.3.2).					
SINZR	/BASES/	IP	real	-	-
Sine of the zone rotation angle (4.1.2).					
SKY	/ENVDAT/	BOTH	real	(24)	C
Sky temperatures (B.3.4).					
SNAME	/Z NAMES/	IP	chr*WRD	-	-
Schedule name.					
SNLOAD	/ZONL/	LC	real	(MAXZON)	Wh
Sensible heating (+) or cooling (-) load in the zone.					
SNOW	/ENVDAT/	BOTH	integer	-	-
Snow indicator (compressed 24 hours).					
SOLDIS	/RUNCTL/	BOTH	integer	-	-
Solar distribution algorithm (3.1.2).					
SPC2	/RUNCTL/	IP	logical	-	-
If true, double space the echo of user input (1.1.4).					
SPD	/ENVDAT/	BOTH	real	(24)	m/s
Wind speed.					
SPHT	/MATDAT/	IP	real	(MAXNL)	kJ/kgK
Specific heat of material (2.4.4).					
SQTRDZ	/ZONL/	LC	real	(MAXZON)	$\sqrt{\text{kg/m}^3}$
Square root of zone air density.					
SQRTV	/AIR/	LC	real	-	$\sqrt{(\text{m/s})}$
Square root of wind velocity.					
SRADBM	/ENVDAT/	BOTH	real	(24)	W/m ²
Intensity of beam solar radiation.					
SRADDF	/ENVDAT/	BOTH	real	(24)	W/m ²
Intensity of diffuse solar radiation (sky brightness).					
SRADGR	/ENVDAT/	BOTH	real	(24)	W/m ²
Intensity of ground reflected solar radiation.					
SREF	/MATDAT/	IP	real	(MAXNL)	-
Reflectance of shade (2.4.12).					

SSCPTR	/HTSISL/	BOTH	integer	(MAXHTS)	-
Pointer to special surface coefficients.					
SSDECL	/ENVDAT/	BOTH	real	-	-
Sine of the solar declination angle.					
ST	/SRFIS/	BOTH	real	(MAXSRF)	-
Sine of the surface tilt angle (3.2.2 and 4.13.4).					
STATM	/BLDRPT/	LC	integer	(6,MAXZON)	-
System status hours: Total for run in 6 categories.					
1 = heating capacity exceeded.					
2 = in heating mode.					
3 = in ventilation mode.					
4 = in cooling mode.					
5 = cooling capacity exceeded.					
6 = no heating, cooling, or ventilating.					
STDTIM	/SIMCTL/	LC	integer	-	-
Standard time (t_s in sec B.1.1).					
STLOAD	/ZONL/	LC	real	(MAXZON)	Wh
Steam load in zone (steam equipment plus steam baseboard heat).					
SUMB	/RF/	IP	real	-	-
Sum of BETA values for all layers.					
SUMC	/ZONL/	LC	real	(MAXZON)	W
Sum of scheduled convective gains.					
SUMDTI	/ZONL	/LC	real	(MAXZON)	-
Sum of outside temperature derivatives.					
SUMHA	/ZONL/	LC	real	(MAXZON)	W/K
Sum of ($HI*AREA$) for zone surfaces (HC_i*Si in K.2.2).					
SUMHAD	/ZONL/	LC	real	(MAXZON)	-
Sum of air temperature derivatives (J.3.4a, J.4.2a, J.5.8a, J.5.10a).					
SUMHAT	/ZONL/	LC	real	(MAXZON)	W
Sum of ($HI*AREA*T$) for zone surfaces ($HC_i*S_i*T_i$ in K.2.2).					
SUMUA	/ZONL/	LC	real	(MAXZON)	W/K
Sum of ($HR*AREA$) for zone surfaces (H.2.5).					
SUMUAD	/ZONL/	LC	real	(MAXZON)	-
Sum of radiant temperature derivatives (J.3.4b, J.4.2b, J.5.8b, and J.5.10b).					
SUMUAT	/ZONL/	LC	real	(MAXZON)	W
Sum of ($HR*AREA*T$) for zone surfaces (H.2.5).					

SUMX	/RF1/	IP	real	(5)	-
Sum of X CTF to test convergence (C.2.1).					
SUMY	/RF1/	IP	real	(5)	-
Sum of Y CTF to test convergence (C.2.1).					
SUMZ	/RF1/	IP	real	(5)	-
Sum of Z CTF to test convergence (C.2.1).					
SUNCOS	/SLPSSH/	BOTH	real	(3)	-
Solar direction cosines.					
SYNTAX	/RUNCTL/	IP	logical	-	-
Process input to only check syntax (1.1.2).					
T	/GLAS2/	IP	real	(2,4)	-
Transmittances of single panes of glass (polarization, pane number).					
T	/HTSL/	LC	real	(MAXHTS)	C
Temperature of inside of surface (or inside movable insulation) for computing mean radiant temperature and convective gain to zone.					
TAU	/GLAS4/	IP	real	(2,4)	-
Energy transmittances of the air-glass interfaces (polarization, interface in direction).					
TBM	/SHDCTL/	LC	real	-	-
Transmittance of window for beam radiation.					
TCNVG	/RUNCTL/	IP	real	-	C
	/SIMCTL/	LC			
Temperature convergence (3.1.3).					
TD	/GLAS0/	BOTH	real	(MAXGTP)	-
Fraction of diffuse solar radiation transmitted through window.					
TE	/ZONL/	LC	real	(MAXZON)	C
Zone effective temperature for control purposes (K.1.3).					
TFH	/BLDTFH/	LC	real	(MAXTFH)	C & W/m ²
Array of surface temperature and flux histories for CTF calculations.					
TGRND	/EFLHDR/	BOTH	real	(12)	C
Ground temperatures (monthly values; 1.4.1).					
TI	/HTSL/	LC	real	(MAXHTS)	C
Temperature of inside of surface.					
TINC	/RF/	IP	real	-	s
Time increment for CTF calculations.					

TMKUP	/EFLHDR/	BOTH	real	(12)	C
Make-up water temperatures (not used).					
TMPHPE	/HTSIL/	BOTH	integer	(MAXHTS)	-
Pointers to external temperature histories.					
TMPHPI	/HTSIL/	BOTH	integer	(MAXHTS)	-
Pointers to internal temperature histories.					
TO	/HTSL/	LC	real	(MAXHTS)	C
Temperature of outside (side away from zone) of surface.					
TR	/ZONL/	LC	real	(MAXZON)	C
Mean radiant temperature of zone (H.2.5).					
TRANS	/MATDAT/	IP	real	(MAXNL)	-
Transmittance of material (2.4.9).					
TRANS	/SRFIS/	BOTH	real	(MAXSRF)	-
Transmittance of shadowing surface (3.2.5 and 4.15.4).					
TRRAIN	/EFLHDR/	BOTH	integer	-	-
Terrain classification (1.3.6 and sec B.4).					
TRTFPC	/CONDAT/	BOTH	real	(MAXCON)	W/m ² K
Cross (Y) temperature conduction transfer functions.					
TRTFPE	/CONDAT/	BOTH	real	(MAXCON)	W/m ² K
External (X) temperature conduction transfer functions.					
TRTFPI	/CONDAT/	BOTH	real	(MAXCON)	W/m ² K
Internal (Z) temperature conduction transfer functions.					
TSD	/GLAS11/	IP	real	(2)	-
Transmittance of shading device (polarization).					
TSHIFT	/BLDTFH/	LC	integer	-	-
Time shift for temperature and flux histories in TFH array.					
TSO	/GLAS11/	IP	real	-	-
Transmittance of shade at normal incidence.					
TT	/GLAS3/	IP	real	(2)	-
Transmittances of layers in a window system (polarization)					
TTB	/GLAS6/	IP	real	(16,2)	-
Transmittances of a window system for beam light (angle number, polarization).					
TTBW	/GLAS8/	IP	real	(16)	-
Beam transmittances integrated over wavelength and polarization (angle number).					

TTD	/GLAS5/	IP	real	(2)	-
Transmittances of a window system for diffuse light (polarization).					
TTDW	/GLAS7/	IP	real	-	-
Diffuse transmittances integrated over wavelength and polarization.					
TVENT	/TCDESC/	LC	real	(5,maxzon)	C
Ventilation control point temperatures.					
TZ	/ZONL/	LC	real	(MAXZON)	C
Zone air temperature.					
TZNR	/EFLHDR/	BOTH	real	-	-
Time zone number (1.3.4).					
T1	/GLAS/	BOTH	(5,MAXGTP)-		
Polynomial coefficients for beam solar transmittance (c_1 in D.1.7a)					
T2	/GLAS/	BOTH	(6,MAXGTP)-		
Polynomial coefficients for beam solar transmittance (c_1 in D.1.7b)					
UCHAR	/UINDAT/	IP	integer	-	-
Current character in line (record) of user input.					
UIERR	/UINDAT/	IP	integer	-	-
User input error:					
	0	no error			
	1	invalid subkey value:			
		continue processing			
	2	invalid subkey name:			
		skip input to next / or) or]			
	3	error in key name processing:			
		skip input to next) or]			
	4	error in section name processing:			
		skip input to next]			
	5	at end of information:			
		set UISTAT=6			
UILINE	/UINDAT/	IP	integer	-	-
User input line number.					
UINREC	/UINREC/	IP	char*80	-	-
User input record (line of 80 characters).					
UISTAT	/UINDAT/	IP	integer	-	-
User input status:					
	0	initial setting in subroutine READER			
	1	at / at end of subkey			
	2	at) at end of key, end subkey also			
	3	at (at end of key name			
	4	at] at end of section			
	5	at [at end of section name			
	6	at end-of-information			

UM	/HTSL/	LC	real	(MAXHTS)	W/m^2K
U-value of movable insulation. 0 means no movable insulation.					
UV	/IZPDAT/	IP	real	-	W/m^2K
U-value of surface for matching interzone surfaces.					
UVAL	/CONDAT/	BOTH	real	(MAXCON)	W/m^2K
Construct U-value.					
VCONV	/ZONL/	LC	real	(MAXZON)	-
Visible to convective factor.					
VMULT	/ZONL/	LC	real	(MAXZON)	-
Visible multiplier.					
VP	/ZONL/	LC	integer	(MAXZON)	-
Pointer to Ventilation control.					
VVF	/ZONL/	LC	real	(MAXZON)	m^3/s
Ventilation design volumetric flow.					
WA	/VERTS/	IP	real	-	degrees
Surface azimuth angle (3.2.1 and 4.13.3).					
WFDAYS	/WFLHDR/	IP	integer	-	-
Number of days on BLAST weather file.					
WFEDAT	/WFLHDR/	IP	integer	-	-
Julian date of last day on BLAST weather file.					
WFEFCD	/WFLHDR/	IP	real	-	-
Cosine of solar declination on first day of BLAST weather file.					
WFEFET	/WFLHDR/	IP	real	-	hr
Equation of time on first day of BLAST weather file.					
WFEFSD	/WFLHDR/	IP	real	-	-
Sine of solar declination on first day of BLAST weather file.					
WFFDAY	/WFLHDR/	IP	integer	-	-
WFFILL	/WFLHDR/	IP	integer	(46)	-
Array filler.					
WFLATD	/WFLHDR/	IP	real	-	degrees
Location latitude of BLAST weather file.					
WFLONG	/WFLHDR/	IP	real	-	degrees
Location longitude of BLAST weather file.					
WFSDAT	/WFLHDR/	IP	integer	-	-
Julian date of first day on BLAST weather file.					

WFSDAY	/WFLHDR/	IP	integer	-	-
Day-of-month of first day of BLAST weather file.					
WFSMON	/WFLHDR/	IP	integer	-	-
Month of first day of BLAST weather file.					
WFSTTN	/WFLHDR/	IP	integer	-	-
Weather station number of BLSAT weather file.					
WFSYR	/WFLHDR/	IP	integer	-	-
Year of first day of BLAST weather file.					
WFTMZN	/WFLHDR/	IP	real	-	-
Time zone of BLAST weather file.					
WL	/GLAS10/	IP	real	(1)	nm
Wavelength at which optical properties are computed.					
WREC	/WFLHDR/	IP	integer	(64)	-
BLAST weather file header array (all values equivalenced to this array).					
WS	/VERTS/	IP	real	-	degrees
Surface slope (tilt) angle (3.2.2 and 4.13.4).					
WSH	/SCHDLS/	LC	integer	(12,MAXWSH)	-
Week-schedules (pointers to day-schedules).					
WSHNAM	/LIBNMS/	LC	char*WRD	(MAXWSH)	-
Names of week-schedules.					
WSTATN	/EFLHDR/	BOTH	integer	-	-
Weather station number.					
WSO	/LIBCTL/	IP	integer	-	-
Pointer to week-schedules (location 0).					
WTITLE	/WFLHDR/	IP	integer	(4)	-
BLAST weather file title.					
WTYPE	/CONDAT/	BOTH	integer	-	-
Window type (=1 if window; =0 if opaque).					
X	/GLAS12/	IP	real	(16)	-
Independent variable ($\cos\theta$) for curve fit.					
X	/VERTS/	IP	real	(4)	m
X-coordinate (surface relative or global) of surface vertices.					
XLLC	/VERTS/	IP	real	-	m
X-coordinate (global) of surface origin (X_{80} in E.1.2a).					

XLOAD	/ZONL/	LC	real	(MAXZON)	Wh
Previous value of zone sensible load.					
XREF	/RUNCTL/	IP	logical	-	-
If true, print cross reference data (1.1.5).					
XTEMP	/HCFS/	LC	integer	(MAXHCS)	-
X homogeneous coordinates of overlap before sequencing.					
XTR	/ZONL/	LC	real	(MAXZON)	C
Previous value of the zone mean radiant temperature.					
XTZ	/ZONL/	LC	real	(MAXZON)	C
Previous value of zone air temperature.					
XV	/SRFIS/	BOTH	real	(4,MAXSRF)	m
X-coordinates (global) of surface vertices.					
XVC	/SHDVRT/	LC	real	(5)	m
X-coordinates (surface relative) of clipped shadowing surface.					
XVS	/SHDVRT/	LC	real	(5)	m
X-coordinates (surface relative) of shadow.					
XVT	/SHDVRT/	LC	real	(5)	m
X-coordinates (surface relative) of shadowing surface.					
XX	/VERTS/	IP	real	(4)	m
X-coordinates (surface relative) of surface vertices.					
Y	/VERTS/	IP	real	(4)	m
Y-coordinates (surface relative or global) of surface.					
YEAR	/ENVDAT/	BOTH	integer	-	-
Year (4 digits).					
YLLC	/VERTS/	IP	real	-	m
Y-coordinate of surface origin (Y_{SO} in E.1.2b).					
YTEMP	/HCFS/	LC	integer	(MAXHCV)	-
Y homogeneous coordinates of overlap before sequencing.					
YV	/SRFIS/	BOTH	real	(4,MAXSRF)	m
Y-coordinates (global) of surface vertices.					
YVC	/SHDVRT/	LC	real	(5)	m
Y-coordinates (surface relative) of slipped shadowing surface.					
YVS	/SHDVRT/	LC	real	(5)	m
Y-coordinates (surface relative) of the shadow.					

YVT	/SHDVRT/	LC	real	(5)	m
Y-coordinates (surface relative) of the shadowing surface.					
YY	/VERTS/	IP	real	(4)	m
Y-coordinates (surface relative) of the surface.					
Z	/VERTS/	IP	real	(4)	m
Z-coordinates (surface relative or global) of surface vertices.					
ZCLD	/BLDRPT/	LC	real	(MAXZON)	Wh
Total sensible cooling load for zone					
ZHLD	/BLDRPT/	LC	real	(MAXZON)	Wh
Total sensible heating load for zone.					
ZLLC	/VERTS/	IP	real	-	m
Z-coordinate of surface origin (Z_{so} in E.1.2c).					
ZMNT	/BLDRPT/	LC	real	(MAXZON)	C
Minimum zone air temperature.					
ZMXC	/BLDRPT/	LC	real	(MAXZON)	W
Peak sensible cooling requirement.					
ZMXH	/BLDRPT/	LC	real	(MAXZON)	W
Peak sensible heating requirement.					
ZMXT	/BLDRPT/	LC	real	(MAXZON)	C
Maximum zone air temperature.					
ZNAMES	/ZNAMES/	LC	char*WRD	(MAXZON)	-
Names of zones.					
ZNAMIN	/ZNAMES/	IP	char*WRD	-	-
Name of current zone.					
ZNMOUT	/ZNAMES/	IP	char*WRD	-	-
Name of far side zone.					
ZNRELN	/BASES/	IP	real	-	degrees
Angle from the building Y-axis (north) to the zone Y-axis (4.1.2 and E.1.2).					
ZNXORG	/BASES/	IP	real	-	m
X-coordinate of zone origin (X_{zo} in E.1.1a).					
ZNYORG	/BASES/	IP	real	-	m
Y-coordinate of zone origin (Y_{zo} in E.1.1b).					
ZNZORG	/BASES/	IP	real	-	m
Z-coordinate of zone origin (Z_{zo} in E.1.1c).					

ZRRS	/RFO/	IP	real	(3)	-
Residues at the double pole at 0.					
ZS	/AFSIL/	BOTH	real	(MAXAFS)	m
Height of the air flow opening.					
ZT	/AFSIL/	IP	real	(MAXAFS)	m
Height of top of surface (for evalauting PW).					
ZV	/SRFIS/	BOTH	real	(4,MAXSRF)	-
Z-coordinates (global) of surface vertices.					
ZVC	/SHDVRT/	LC	real	(5)	m
Z-coordinates (surface relative) of clipped shadowing surface.					
ZVMOD	/AFSIL/	BOTH	real	(MAXAFS)	-
Height modifier for computing wind pressure.					
ZVS	/SHDVRT/	LC	real	(5)	m
Z-coordinates (surface relative) of the shadow (= 0).					
ZVT	/SHDVRT/	LC	real	(5)	m
Z-coordinates (surface relative) of shadowing surface.					
ZZ	/ZONISL/	BOTH	real	(MAXZON)	m
Height of zone for computing zone pressure.					

VI.D FILES

INPUT PROCESSOR FILES:

UNIT	FILE	ACCESS	DESCRIPTION
11	SINPFL	seq	Simulation input file
12	ENVTFI	dir	Environment file
13	WTHRTP	seq	Weather tape from BLAST program
14	-	dir	Materials data
15	-	dir	Constructs data
16	-	dir	Interzone surface data
17	-	dir	Interzone opening data
21	-	seq	Day-schedules library report
22	-	seq	Week-schedules library report
23	-	seq	Materials library report
24	-	seq	Constructs library report
25	-	seq	Control profiles library report
26	-	seq	Control day-schedules library report
27	-	seq	Control week-schedules library report

LOADS CALCULATOR FILES:

11	SINPFL	seq	Simulation input file
12	ENVTFI	dir	Environment file
13	-	dir	Solar gains multipliers
14	-	seq	Input segment to loads segment data
15	-	seq	Input segment to shadowing segment data

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET <i>(See instructions)</i>	1. PUBLICATION OR REPORT NO. NBSIR 83-2655	2. Performing Organ. Report No.	3. Publication Date February 1983
4. TITLE AND SUBTITLE Thermal Analysis Research Program Reference Manual			
5. AUTHOR(S) G. N. Walton			
6. PERFORMING ORGANIZATION <i>(If joint or other than NBS, see instructions)</i> NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			7. Contract/Grant No. 8. Type of Report & Period Covered
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10. SUPPLEMENTARY NOTES <input type="checkbox"/> Document describes a computer program; SF-185, FIPS Software Summary, is attached.			
11. ABSTRACT <i>(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)</i> The Thermal Analysis Research Program (TARP) has been developed as a research tool for the thermal analysis of buildings. It especially aims to study the interactions of many complex heat transfer phenomena. TARP uses the detailed heat balance method for the simultaneous calculation of the energy requirements of multiple rooms. Interroom conductive and convective processes are simulated in detail. This program reference manual describes the algorithms, input, output, and program structure of TARP. The program is written to be portable and modifiable. It is written in FORTRAN 77 and has run on CDC and UNIVAC computers. Future expansions of the program are anticipated, particularly for the simultaneous simulation of equipment performance and building thermal response.			
12. KEY WORDS <i>(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)</i> Building energy analysis; load calculation; computer modeling; building heat transfer.			
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